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Environmental Protection Department
Hazardous Waste Management Division

Preliminary Safety Analysis Report for the Site 300 Explosives Waste Treatment Facility and Building 816

Prepared by

Jo Ellen Neuman
Robert W. Myers
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Documents and Assessments Group

March 1995

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University of California   Livermore, California 94551

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List of Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations
DOD	Department of Defense
DOE	Department of Energy
EPI	Emergency Prediction Information
ERPG	Emergency Response Planning Guide
ES&H	Environment, Safety, and Health
EWSF	Explosive Waste Storage Facility
EWTF	Explosive Waste Treatment Facility
FSP	Facility Safety Procedure
HE	High Explosives
HWM	Hazardous Waste Management
LLNL	Lawrence Livermore National Laboratory
M&TE	Measurement and Test Equipment
NEW	Net Explosive Weight
NFPA	National Fire Protection Association
OBU	Open Burn Unit
ODU	Open Detonation Unit
OSHA	Occupational Safety and Health Administration
OSP	Operational Safety Procedure
PFD	Protective Force Department
PSAR	Preliminary Safety Analysis Report
QA	Quality Assurance
TLV-C	Threshold Limit Value - Ceiling
TLV-TWA	Threshold Limit Value - Time -Weighted Average
UNO	United Nations Organization

1. Introduction

1.1 Executive Summary

This Preliminary Safety Analysis Report (PSAR) is for the Explosives Waste Treatment Facility (EWTF) at Building 845 (B845) and for Building 816 (B816) at Site 300, Lawrence Livermore National Laboratory (LLNL). The report was prepared in accordance with U.S. Department of Energy (DOE) Order 5481.1B (DOE, 1987), Management Directive 5481.1A (DOE, 1989a), and Title 29 *Code of Federal Regulations* (CFR) 1910.119. The EWTF will be used to destructively dispose of explosives waste, including many high explosives materials. B816 will be a part of the Explosives Waste Storage Facility (EWSF) and will be used to store explosives-contaminated waste. Based on the handling and storage of explosives described in this report, the EWTF is classified as a moderate hazard, low-risk facility, and B816 as a single building is classified as a low hazard, low-risk facility

. The moderate hazard classification was assigned by evaluating the consequences of bounding accidents for explosives in accordance with DOE Order 5481.1B; the classification assignment was also based on the approach for risk analysis of hazardous materials currently used at LLNL.

The moderate hazard, low-risk determination assumes that administrative controls will prevent changes in inventories from exceeding the maximum values used in this analysis. Changes in operations, maximum inventories, locations, materials, Level of Protection criteria (DOE, 1994a), Quantity-Distance (Q-D) criteria, or release potential that could result in the bounding consequences being exceeded or that could negatively affect the safety of operations in these facilities will require a reevaluation of the classification and the level of risk.

1.2 Introduction

The information in this section describes the facility and the protection afforded the environment and the health and safety of workers and the public. This report documents the preliminary safety and risk analysis for the EWTF and B816. In summary, it provides:

- A general description of the sites, the facilities, and their operations.
- A systematic identification of the hazards of the facilities and operations.
- Details of the hazards analysis and the risk analysis including inventories, bounding releases, qualitative probabilities, consequences, and conclusions.
- Conduct of operations and operational safety requirements.
- Quality assurance.

As part of the safety analysis procedure set forth by DOE, a PSAR must be performed for the EWTF and B816 (DOE, 1987; DOE, 1989a). The PSAR characterizes the level of potential hazard associated with the planned facility and associated operations, and it provides the basis for hazard classification and the determination of the acceptability of risk.

The hazards of primary concern associated with the EWTF and B816 are unintentional explosives detonations or deflagrations. The hazard classification is determined by reviewing the operations performed in the existing facilities, the drawings and conceptual design package, records of previous explosives handling accidents, and the operating history of all Site 300 explosives facilities. For the hazard classification, the consequences of the bounding events are evaluated assuming that all active barriers fail (unmitigated events). In this way, the intrinsic hazard level and the basis and residual risks can be evaluated and determined. By postulating and evaluating bounding accidents associated with the hazards of greatest significance and assigning each a likely frequency range, the acceptability of risk is determined for each facility. For the purposes of the acceptability of risk analysis, credit is assumed for barriers; however, the frequency of barrier failure is evaluated as part of the risk analysis and that barrier becomes a safety system subject to conduct of operations, audits, and all DOE safety system requirements.

Additional risk-related information is available for environmental releases. The reader is referred to the Final Environmental Impact Statement and Environmental Impact Report (DOE, 1992), hereafter referred to as the EIS.

2. Summary and Conclusions

As designed, the EWTF and operations will dispose of explosives wastes by carefully planned open burnings and open detonations. Employee training, written procedural controls, earth barricades, and remote operations represent the most effective safety controls for these operations. However, due to the nature of handling these highly energetic materials, the potential for an unintentional detonation or deflagration exists. The analyses of the consequences of several worst-case accidents have been determined and details are presented in Section 4. No adverse effects or significant environmental impacts are expected due to operations of the EWTF and B816.

A summary of the worst-case consequences include the extremely unlikely possibility of explosives handler fatalities due to an accidental detonation or deflagration, and the potential for major facility loss. In the unlikely event of a worst-case accident, off-site effects are limited to (1) broken windows and (2) impulse noise exceeding 126 dB. Due to the impulse nature of this noise, no adverse health effects are expected. Because of the remote location of Site 300, the small quantities of wastes treated at any one time, and the short duration of treatment, the off-site airborne concentrations of the products of decomposition will not pose adverse health effects to the public.

3. Description of Site, Facilities, and Operations

3.1 Site Characteristics

The EWTF and B816 will be built on LLNL Site 300, which is 24 km (15 mi) east of Livermore, California, and 105 km (65 mi) southeast of San Francisco, in rugged terrain on the east side of the sparsely populated Altamont Hills (see Figure 1). Site 300 covers an area of approximately 28.5 km^2 (11 mi^2) and consists of mostly undeveloped land. About one-sixth of Site 300 is in Alameda County; the remainder, including the EWTF and EWSF, lies in San Joaquin County.

The topographic surface of Site 300 is characterized by steep hills and rugged canyons, although rolling hills and flat benches exist in the southern portion. Elevations at Site 300 range from as high as 525 m (1,722 ft) above sea level at the northwest corner, to as low as 152 m (500 ft) at the southeast corner. The EWTF consists of two Open Burn Units (OBU), an Open Detonation Unit (ODU), and a control bunker. The EWTF units are located in the central part of Site 300 in distinct ravines. The OBU and the ODU are separated by a distance of approximately 274 m (900 ft). The OBUs are sited at approximately 319 m (1,045 ft) above mean sea level, and the ODU is sited at approximately 328 m (1,075 ft) above mean sea level. B816 will be located at the EWSF, which is approximately 2.5 km (1.5 mi) southeast of the EWTF. The EWSF will consist of five existing magazines (M1–M5) and B816, which is approximately 290 m (950 ft) above mean sea level.

3.1.1 Geography and Demography

Tracy, which is the nearest residential center, is located approximately 13 km (8 mi) east-northeast of the Site 300 entrance. As shown in Figure 2, the land surrounding LLNL Site 300 is primarily used for livestock grazing and wind farms. The Carnegie State Vehicle Recreation Area, located to the south of Site 300, is an outdoor recreational facility used for private and commercial off-road motorcycle riding, testing, and racing. The California Department of Forestry operates the Castle Rock Fire Station, located on the Connolly property on Corral Hollow Road near the southeast corner of Site 300. Stanford Research Institute International operates an explosives test site in the hills south of the Carnegie property. Physics International operates an explosives test site at the eastern boundary of Site 300.

3.1.2 Meteorology

The climate in and around LLNL Site 300 is generally characterized by mild winters with low rainfall and hot, dry summers. Sunshine is abundant in the area throughout the year. The area is described in *Environmental and Exposure Assessment (EA), SubPart X* (LLNL and Radian, 1993a) as a "Mediterranean Scrub Woodland" climate. During nonrainy periods, particularly during December and January, fog forms in the San Joaquin Valley and moves over the site.

Based on data collected at the Site 300 on-site meteorological station and presented in the EIS (DOE, 1992), the average annual rainfall is approximately 26.3 cm (10.34 in.). Mean daily temperatures for the years 1951–1980 were reported as 14.5°C (58.1°F) mean, with daily extremes ranging from –8°C (18°F) to 45°C (113°F).

Figure 3 represents wind roses extracted from the EIS (DOE, 1992), which depicts average data on annual and seasonal wind direction and speed for Site 300. As shown, the predominant wind direction is from the west-southwest. Data were collected at the Site 300 weather station at a height of 10 m (32.8 ft) on the meteorological tower. During the 1987–1990 time period, the wind was from the west-southwest approximately 32 percent of the time. Approximately 4 percent of these winds from the west-southwest direction displayed speeds greater than 11 m /s (36 ft/s).

Lightning may occur periodically during the year, normally associated with storm phenomena. The potential for lightning is monitored at Site 300 and is discussed later in this document.

3.1.3 Hydrology

A brief synopsis of hydrological information is provided in this section. For a thorough discussion, see the EIS (DOE, 1992). The EWTF is located in the central part of Site 300 in two distinct ravines and separated by a distance of approximately 274 m (900 ft). The ODU is located in a ravine that slopes approximately 10 degrees to the northeast. Parallel ridges rise approximately 46 m (150 ft) west and 30.5 m (100 ft) east of the ODU. The open burn area lies in a ravine that slopes approximately 10 degrees to the east. Ridges rise approximately 30.5 m (100 ft) north and 30.5 m (100 ft) south of the open burn area site, and the surrounding hillsides are sparsely vegetated.

The depth to groundwater beneath the EWTF varies from 24 m (80 ft) to 40 m (130 ft) below ground surface. The first water encountered under the EWTF is confined and correlated to the main aquifer present throughout LLNL Site 300. Groundwater near the EWTF is not used as a water supply. The nearest water supply wells are W-18 and W-20, which are located approximately 3.2 km (2 mi) southeast of the EWTF, near the general services area along Corral Hollow Road. Both of these wells are approximately crossgradient of the EWTF.

3.1.4 Geology and Seismology

This section provides a brief overview of the geological and seismological information related to Site 300. For a detailed treatment of the subject, see *Operational Plan for Site 300 EWTF* (LLNL and Radian, 1993b). The Elk Ravine Fault, in the north-central part of the site, and the Corral Hollow-Carnegie Fault Zone, in the southwestern portion, are the two known fault zones within Site 300. The EWTF site is not located within an Alquist-Priolo Special Studies Zone, as determined by the State of California. The Elk Ravine Fault Zone, which is the only known fault feature within 0.9 km

(3,000 ft) of the proposed EWTF, lies approximately 213 m (700 ft) northeast at its closest point.

3.2 Facility Description

At Site 300, explosives waste will be stored at the EWSF, of which B816 will be a part, and treated at the EWTF, which will consist of two treatment facilities. This PSAR will give a brief description of the EWSF but cover only B816, the only new building at the EWSF. The storage magazines will be covered in the safety analysis for magazine operations. The EWSF is located 1,075 m (3,525 ft) from the eastern border of Site 300 and 1,210 m (3,975 ft) north of Corral Hollow Road.

The EWSF will be comprised of five existing, earth-covered concrete magazines (M1–M5) and a single new building (B816) for storage of explosives-contaminated waste. These magazines previously used for explosives storage will now be used to store only explosives classified as waste. B816 will be a corrugated metal building which will meet manufacturer's specifications for utility (non-occupancy). It will be erected in the vicinity of the EWSF.

The EWTF will be located at a point that is approximately 2,290 m (7,500 ft) from the northernmost property line and 1,900 m (6,225 ft) from the eastern property boundary. It consists of the ODU and the two OBUs (see Figure 4). Figure 5 shows the proposed location of the OBUs and Figure 6 shows the proposed ODU location. The OBUs and the ODU will use a common control bunker, B845, which is existing but will be modified and outfitted with the control systems to remotely operate and monitor both the ODU and OBUs. Figure 7 shows B845's location, below and downgradient of the proposed ODU location. Remote ignition and initiation capability will be provided for the respective units.

The OBU will be located approximately 213 m (700 ft) north-northeast of B845. It will be comprised of the burn pan and burn cage, which are described in more detail below. The support area of the open burn area contains the equipment storage building, magazette, propane tank, and utilities. The 23-m^2 (250-ft^2) storage building will store the combustible materials used to initiate burning operations. The magazette storage structure, located no less than 15 m (50 ft) from the open burn storage building, will be specially designed for the storage of explosives, such as squibs, blasting caps, and other initiators. The support area will be separated from the burn pan and burn cage by an earthen barricade. The open detonation pad will be approximately 30.5 m (100 ft) from B845. The specific design features of the ODU are described in detail below.

3.2.1 Principal Design Criteria

The design criteria include statutory, regulatory, administrative, and consensus standards requirements. Table 1 presents the typical design criteria and the status of the design element with respect to the specific or general criterion(ia).

3.2.1.1 Design Features

The design features of the EWTF and B816 are comprised of *Engineered Controls,* which include siting elements, design, topographical features, safety systems and components, and are described within this section. *Administrative Controls* which include procedural and operational restraints are described in Section 3.3.3. *Personnel Controls* which include training and qualification of staff will also be addressed in Section 3.3.3.

All three of these types of controls will be incorporated into an integrated design developed to provide multiple barriers to the potential accidents postulated in this PSAR.

Engineered Controls

The siting of the proposed EWTF units takes advantage of the passive design characteristics of the ravines intrinsic to the topography. The sides of the ravines act as natural earthen barricades that passively mitigate the hazards associated with potential of treatment-generated fragment or debris projectiles, although they do not mitigate blast overpressure effects.

Fire protection for grass fires will be partially mitigated by a combination of fuel elimination or reduction through the maintenance of fire breaks of approximately 61-m (200-ft) width around the OBUs and ODU.

For the open detonation pad, design features include the planned pea gravel base of approximately 1-m (3-ft) depth minimum. This feature provides for a shock absorption capability which mitigates the effects of the physical blast forces (ground shock) conducted to the bunker. Production of fragments is minimized by removal of large rocks (greater than 6 in. or 10 lb), metal debris, etc., from the detonation pad. B845 is designed to protect personnel from fragments, thermal flux, and hazardous overpressures.

In the open burn area, the two units provide for physical containment of the thermally treated materials. In the case of the open burn pan, this design will include a metal base and metal sides creating a depth of 15 cm (6 in.). The proposed burn pan design will be capable of being remotely covered, following completion of combustion, to control ashes; however, the intent is not to have the treatment area covered at the time of combustion. It is important that the pan remain uncovered during thermal treatment, because confining the combustion reaction could cause a detonation due to increases in the temperature and pressure. Further design analysis may show that the hazard of the cover exceeds the benefits of fire protection or prevention of ash dispersal.

The OBUs will have elevated unit bases that will allow for ease of handling and decrease the likelihood of mishandling the waste to be thermally treated. This design element will also partially mitigate the occupational health hazard of back injury.

The propane tank (supplemental fuel as described below) will be protected by an earthen barricade which will mitigate possible thermal treatment-generated missiles or projectiles from impinging the tank. The risks associated with propane shall be addressed by adherence to recognized industrial engineering standards for its safe use.

Grounding protection will be employed in the protection of all metal structures or substructures to mitigate the possibility of static electrical discharge. As described below, spark elimination and/or avoidance provides additional passive protection from unintended initiation of the explosives.

The EWSF has or will have lightning arrestors installed at each existing magazine and B816. Each magazine wing wall (to the right of the entry) and the proposed storage building (B816) will have an alarm button to actuate the klaxon alarm (see drawing PSZ93816001D). The klaxon is an audible area alarm that signals emergency conditions. Other design features of the magazines will be covered in the safety analysis to be done for Site 300 magazines.

Electrical circuitry at both the EWSF and EWTF will be installed according to National Fire Protection Association (NFPA) requirements and the *DOE Explosives Safety Manual* (DOE, 1994a) as applicable. Cabling for electrical circuits will be buried or laid in trenches to avoid the possibility of severance which could initiate explosives during setup. Initiation/ignition interlock circuits will be installed which include interlocks to the gate access point of the EWTF combined treatment area. This system will effectively mitigate the likelihood that an initiation signal can be generated without the cognizant operator consciously assuring that all required safety systems are in place.

The open burn cage will have a supplemental fuel source that will enhance the thermal treatment process. This fuel will be propane or other suitable compressed gas which will be ignited by a glow plug or piezoelectric ignitor remotely actuated from B845. This system will be initiated by the above-referenced, interlock ignition system. The supplemental fuel system will be capable of control from the B845 control center. This control will include metering and an on/off control switch.

The propane tank and associated piping and controls subsystems provide an additional energy source to the combustion chamber of the open burn cage. This design ensures complete thermal treatment and substantially mitigates the possibility of explosive material residue which could unexpectedly initiate. Because the propane tank and its associated piping and valves pose an ignitable source, it will require an inspection and/or monitoring program.

The thermal treatment units, ODU and OBUs, will be capable of being remotely monitored visually by an operator-controlled, closed circuit television system (CCTV). The system will have zoom and horizontal pan capability and adjust vertically relative to the horizon. These capabilities will be controllable by the operator from within B845.

The B845 control area will have meteorological data available (on a near real-time basis) that will allow the operator to determine if the weather conditions have changed significantly since the thermal treatment setup was accomplished. This precaution will mitigate the grass fire potential, inappropriate atmospheric dispersal conditions, and pressure refraction conditions associated with atmospheric thermoclines.

The grounds surrounding the treatment units and loading areas will be kept free of combustible debris. A 15-m (50-ft)-wide vegetation clear area will be maintained around each structure at the EWSF, including B816 and each structure at the EWTF. The EWTF will be surrounded by 61-m (200-ft)-wide firebreaks that are not required to be devoid of vegetation, although the growth of vegetation will be controlled to prevent fire from spreading. A controlled burn is performed annually to limit vegetation volume that might feed a grass fire.

An operable telephone will be available prior to initiating thermal treatment operations. The Site 300 Protective Force Department (PFD) Console Operator and Fire Station II will be notified of the intended ignition five minutes prior to igniting the material. The Console Operator will announce over the radio that a controlled burn will take place in five minutes. The Fire Department will notify the Technician-in-Charge when it is unable to properly respond to a potential emergency. Thermal treatment operations will not take place when the Fire Department is unavailable to respond.

The telephone system provides communications capability without the electromagnetic hazard associated with radio transmission. This system will be available at both the EWTF and EWSF.

3.2.2 Facility Design and Siting

As mentioned above, the EWSF magazines are existing structures and will not be further discussed here but will be addressed in the safety analysis to be done for all Site 300 magazine operations. B816, intended for the storage of explosives-contaminated waste, will be a simple utility metal shed. No special design criteria are required for this structure.

The design of the EWTF is currently developed to meet the pre-Title 1 requirements sufficient for RCRA permit application. The details of the design are thus still changeable and will be definitively covered in the FSAR.

The cardinal principle to be observed at any location or in any operation involving explosives, ammunition, severe fire hazards, or toxic materials is to limit the exposure to a minimum number of personnel, for a minimum time, and to a minimum amount of the hazardous material, consistent with safe and efficient operation *(DOE Explosives Safety Manual* [DOE, 1994a]). Three sets of criteria are used to minimize the exposure of personnel. These criteria are:

- DOE Level of Protection Criteria
- DOD Quantity-Distance Criteria
- Noise Protection Criteria.

The DOE Level of Protection criteria set acceptable levels of protection for explosives activities and are based on the hazard class (accident potential) for the explosives activity involved. Four hazards classes are set forth in *DOE Explosives Safety Manual* (DOE, 1994a). These are briefly summarized below.

Class I

Class I consists of activities involving a high accident potential that require remote operations. This category includes such actions as machining explosives, explosives development, and explosives disposal. Intentional thermal destruction is included in this class.

Class II

This class includes activities of a moderate accident potential. Setup of thermal destruction processes or setup of destruction shots are included in this class.

Class III

This class includes those activities incidental to storage, or removal from storage, of the explosives materials.

Class IV

This class involves activities with insensitive high explosives (IHE) or IHE subassemblies.

Both Class I and Class II apply to explosives disposal operations. Class II applies during setup of the operation while Class I applies during the actual detonation or burning operation.

The protection criteria for each class are set forth in *DOE Explosives Safety Manual* (DOE, 1994a), Chapter VI, Section 4.2. These criteria are summarized in Table 2. To meet these level of protection criteria for personnel protection, DOD Quantity-Distance (Q-D) K factors and “minimum fragment distances” are used.

The DOD Q-D criteria are based on the hazard classification of explosives. Explosives are classified within a system developed by the United Nations Organization and are included within Class 1 of this system, which is further divided into six divisions:

Hazard Class and Division	Hazards
1.1	Mass explosion
1.2	Non-mass explosion, fragment producing
1.3	Mass fire, minor blast, or fragment
1.4	Moderate fire, no blast or fragment
1.5	Explosive substance, very insensitive
1.6	Explosive article, extremely insensitive

Hazard Class / Division 1.1 explosives present the greatest hazard for a given weight. LLNL therefore bases design analyses upon the assumption that all inventory weights for facility design are considered to be Category 1.1.

Design of facilities is controlled by facility siting (separation) considerations of Q-D relationships (published by DOD). These separation requirements are based on the type of activities performed in each facility and the acceptable level of injury and damage at the facility. A specific K factor relating to the incident overpressure is used to determine the required separation distance based on using the formula :

$$D = KW^{1/3}.$$

The parameters are defined as: D is distance in feet, K is a factor depending upon the risk assumed or permitted and directly related to the overpressure generated, and W is the net explosives weight. All calculations are based on the maximum net explosives weight permitted in the facility.

DOE has defined special Q-D requirements for explosives disposal activities. Destruction by detonation activities are required to be separated from storage magazines, inhabited buildings, public traffic routes, and occupied operating buildings to ensure that personnel are not exposed to hazardous blast overpressure, fire brands, fragments, or projectiles. A danger zone is to be established based upon a 328 K factor.

At low explosives quantities, and especially when dealing with Class / Division 1.2 explosives, considerations about fragments override the effects of overpressure because the hazardous fragment throw range is significantly greater than the hazardous blast overpressure range. This is also true for disposal and intentional detonation operations. Thus, minimum fragment distances are established by DOD to further protect personnel from high-speed, low-angle fragments and from lower-speed, high-angle fragments. These minimum fragment distances override any lower distance based on a K factor.

When the facility design and siting account for the required K factors in the formula as noted above and the minimum fragment distances, then the facility is capable of being operated at an acceptable level of risk with respect to the maximum net explosive weight of consideration. Applicable Q-D considerations of burn pad vs. burn cage distance will be reconfirmed during the detailed design process.

To protect exposed personnel from the impulse noise levels associated with planned detonation activities, an OSHA-required maximum sound exposure of 140 dB is considered. This noise level corresponds to a 585 K factor and is considered in assuring the adequacy of the muster zone radius.

The three sets of criteria—DOE Level of Protection, DOD Q-D, and OSHA noise—may be met by appropriate facility structural design elements or by assuring the siting of facilities an adequate distance from the thermal operations and access control of personnel inside the danger zone.

Table 3 summarizes the appropriate distance requirements associated with the closest exposure of each major exposure category to each Potential Explosion Site, and the currently established maximum weights for each Potential Explosion Site. If the distances as noted are met by the siting of the facility or by its structural design elements, the facility is defined as operable at an acceptable level of risk.

The OBU will consist of the burn cage; burn pan; burn supply storage building; magazette; earth-barricade-protected, 568-L (150-gal) propane tank; safety shower; and eyewash station.

As designed, the burn pan will be a 4-ft × 8-ft steel pan, approximately 6 in. deep, mounted on steel legs, with a remotely controlled movable cover. After treatment is complete, the remotely operated cover will be moved into position over the pan to contain the residual ash until it can be safely removed. This cover will be controlled by a reversibly controlled motor drive according to Drawing No. AAA88-1000925-0A, *Operational Plan for Site 300 EWTF* (LLNL and Radian, 1993b).

As designed, the burn cage is a metal enclosure measuring 5 ft × 9 ft, with a sloped roof, metal-screened ends, and an elevated metal base. The unit will be lined with fire brick and will contain a propane-fueled burner. A detailed drawing of the burn cage is provided as Drawing No. AAA92-101341-00 of the *Operational Plan for Site 300 EWTF* (LLNL and Radian, 1993b).

The detonation pad, as designed, consists of a 30-ft × 30-ft (size to be finalized in later design stage) level gravel pad a minimum of 3 ft thick. The detonation pad will be located, as a minimum, the required Q-D distance away from B845 to protect personnel from a 350-lb disposal shot. Detonation of explosives wastes is done remotely with the use of high energy detonators or other initiating devices.

Monitoring of OBU operations will be done from B845 with video monitors inside B845 and CCTV surveillance cameras mounted near the treatment units. The system will have the capability to pan 270 degrees, tilt 45 degrees and zoom (limits to be determined) for view control from the remote control and observation center within B845.

The EWTF and B816 will have safety shower and eyewash stations installed. This measure will provide for personnel safety in the event of skin or eye contact with a chemical.

The reinforced concrete magazette currently in use at the existing B829 facility will be relocated to the OBU upon commissioning. It will be used to store electroexplosive devices (EEDs) and other initiators.

Figure 8 shows the location of the burn cage, burn pan, storage building, propane tank, magazette pad, and surveillance cameras within the open burn area.

3.3 Process Description

The EWTF is particularly unique with respect to the normal considerations of PSARs. Generally, PSARs focus on the prevention of the sudden release of potential energy of the material within the process. Here, however, this potential energy release is the primary design intent, i.e., to release the potential energy of detonable materials or other high energy containing wastes. The accidental detonation of waste at the open detonation site represents, primarily, a personnel hazard associated with the possibility of premature detonation. The detonation of small amounts of explosives at the open burn area is also possible. The facility process as described below is such that the effects of intentional detonation or a detonation coincident with thermal treatment will be minimized or rendered inconsequential.

Air emissions are also a characteristic of all thermal treatment operations. These operations are allowed under hazardous waste regulations because other conventional methods of waste treatment or disposal are not as safe or as effective for handling explosives wastes. The potential for impacts from these emissions depends on the combustion products formed.

3.3.1 Process Overview

Open Detonation Unit

The ODU consists of an open detonation pad and the B845 control room bunker. Pieces of explosives waste that cannot be reused, recycled, or treated in the open burn area will be detonated on the open detonation pad. Pieces will be placed on the gravel pad by handlers and then detonated by remote control from the operations bunker control room.

Initiation of detonation in the explosives wastes will be done with the use of initiators / detonators or other initiating devices and will be controlled from B845 under observation by surveillance cameras. Treatment by detonation normally results in the complete conversion of explosives wastes to gases and inert carbon ash.

The major products of treatment (greater than 1 percent by volume) are: solid carbon, carbon monoxide, carbon dioxide, water, and nitrogen. Other products of treatment (less than 1 percent by volume) can include: hydrogen cyanide, nitric oxide, nitrogen dioxide, and ammonia. Only the solid carbon would remain as waste ash after detonation. If the explosives contain a halocarbon binder, the detonation products will include hydrogen fluoride or hydrogen chloride.

Open Burn Pan

Explosives waste and pieces of explosives waste that are small enough to be safely burned will be treated in the metal burn pan. Combustible materials, such as straw and kerosene, will be burned to aid the treatment (ensure complete combustion) of explosives waste in the open burn pan. Open burn operations will be performed remotely and monitored by CCTV.

After treatment and a 24-hr minimum cooling period, the ash residue will be visually inspected by the facility operator or another qualified individual to verify complete treatment (i.e., no untreated waste present). If untreated waste is present, an additional treatment cycle will be conducted to complete treatment of the waste. The possible products of combustion are listed above.

Open Burn Cage

Clarifier waste sludges, explosives-contaminated packing material, explosives-contaminated laboratory waste, and small quantities of explosives powders will be treated in the burn cage. A propane-fueled burner in the burn cage provides supplemental energy (heat) to aid the treatment of the explosives waste. Open burn operations will be performed remotely and monitored by CCTV. After treatment and a 24-hr-minimum cooling period, the ash residue will be visually inspected by the facility operator or other qualified individual to verify complete treatment (i.e., no untreated waste present). If untreated waste is present, an additional treatment cycle will be conducted to complete treatment of the waste. The possible products of combustion are listed above.

3.3.2 Hazardous Materials of Process

The explosives waste handled and treated at the EWSF and EWTF are hazardous in that they can deflagrate or detonate and are sensitive to various energy input sources. Particular caution must be exercised in storing and handling. Some of the wastes are toxic, irritating to eyes, skin, and the respiratory system. Additionally, some of the products of thermal treatment are toxic and are contained in a gaseous cloud whose dispersal is subject to atmospheric conditions.

When an individual waste is generated, the generator is responsible for identifying, characterizing, and packaging such waste prior to their shipment to the EWSF. All containers must be labeled with LLNL Explosives Identification Tags, examples of which can be found in the EWSF Operational Plan (LLNL and Radian, 1992). The HWM Division is responsible for subsequently identifying, characterizing, and shipping the stored wastes for treatment at the EWTF. Generators and HWM Division personnel characterize waste using the criteria identified in Tables 4 and 5. Table 5 presents a summary listing of the waste forms associated with energetic materials research and development operations. Forms 1–4 will be treated at the EWTF. Prior to commissioning, administrative procedures will be developed or revised as applicable to establish the steps for the segregation of Waste Forms 4 and 5. Form 4 will be stored at B816. Table 5 summarizes information about each of the waste forms managed at the EWSF and EWTF, including U.S. Environmental Protection Agency (EPA) waste codes, California waste codes, hazardous waste properties, estimated monthly and annual quantities, and EWTF design capacities. A list of pure explosives compounds, additives, and binders of interest to LLNL and other DOE programs is available in the *Operational Plan for Site 300 Explosives Waste Storage Facility* (LLNL and Radian, 1992).

All hazardous waste transported to the EWSF and EWTF is accompanied by a Hazardous Waste Disposal Requisition form. This form, the “LLNL Hazardous Waste Disposal Requisition Instructions,” and the “Instructions for Documenting Wastes” are presented in the EWSF Operation Plan (LLNL and Radian, 1992). Once the waste is received at the EWSF, a specific location is assigned for storing it and a written log is updated. This log records an inventory of acceptance, location, and disposition of all wastes (whether the waste has been thermally treated or shipped off site). Once waste is received at the EWTF, a specific treatment unit is assigned for its treatment and a written log is maintained that records the treatment of all wastes and inventories all waste material accepted for treatment.

The Waste Analysis Plan for the EWSF and the EWTF is contained in either of the facility’s Operational Plans (LLNL and Radian, 1992; LLNL and Radian, 1993b). This plan details the waste sampling procedures, sample handling, parameters for analysis, test methods used to obtain results, frequency of sampling and analysis, and compatibility issues for containers of explosives waste.

The products of energetic material combustion are difficult to determine. The materials of interest and the majority of the expected wastes at the EWSF and EWTF are C-H-N-O compounds in the form of high explosives. These materials are similar to common hydrocarbons except they contain large quantities of nitrogen and oxygen. Combustion products of energetic materials are similar to those observed in the burning of hydrocarbons (e.g., wood or gasoline) with the exception of the production of nitrogen gas. Most explosive materials contain binders and other additives (typically ≤10 weight %). These materials produce similar combustion products to pure explosives with the exception that some binders and additives contain fluorine and chlorine.

One method to determine <u>detonation</u> products (not combustion products) is detonation calorimetry. This method, developed at LLNL, measures product compositions resulting from detonations in the absence of air. These product compositions are different from what would be determined in air since, in the latter case, an abundance of oxygen is available for complete oxidation. Direct determination of the products of combustion in air is very difficult. Reliable results of such experiments are unknown.

Another approach is to perform a mass balance on the reaction, assuming that all of the atoms combine into the simplest products possible. The actual products of combustion are probably somewhere between the calculations for each approach; the products depend upon how completely the combustion process occurred. Three sources of information were available: the *Environmental Assessment for the High Explosives Applications Facility at LLNL* (DOE, 1989b); an LLNL report on bomb calorimeter tests (Ornellas, 1982); and a mass balance. For those compounds of known toxicity, the values are tabulated in Table 6. To be conservative, the highest value for the source term was chosen for each, and these are shaded. These values were used with the mass of explosives determined in the accident scenario to model the dispersion in Emergency Prediction Information Code (EPIcode).

3.3.3 Safety Support Systems

As described in Section 3.2.1.1, this section contains a description of the administrative controls and personnel controls that are combined with the engineered controls to form an integrated design and operation package to assure a safely operated facility.

Administrative Controls

The Management Practices section of the *Operational Plan for Site 300 Explosives Waste Treatment Facility* (LLNL and Radian, 1993b) and the *Operational Plan for Site 300 Explosives Waste Storage Facility* (LLNL and Radian, 1992) describe the safety features of the equipment that will be used to handle the wastes. This material handling equipment will have the following features: backfire deflectors, spark arrestors, deflector plates, fire extinguishers, and rollover protection devices. Wastes are to be stored and moved using approved containers that are labeled indicating the material, storage compatibility group, and net explosives weight. After treatment, ash will be manually removed from the treatment units and placed in containers. Personal protective equipment, which includes cotton undergarments, flame retardant coveralls, safety glasses, gloves, boots, and respirators, will be available to all personnel at all times.

The following paragraphs describe the procedures that ensure that the operation of the EWTF and B816 are accomplished safely. Except where noted, these procedures are taken from the Operational Safety Procedure (OSP) for the existing thermal treatment area, B829 (LLNL, 1995). A new Facility Safety Procedure (FSP) for B845 will be developed based on these practices and the B Division Site 300 Firing Facilities FSP (LLNL, 1994a).

Waste will be treated during the same day that it is moved to the EWTF. There, the amounts of waste that can be treated at one time in one unit will be limited, and the frequency of use of each unit will be limited. These amounts are 159 kg (350 lb) for the detonation pad; 68 kg (150 lb) of pieces that are not larger than 3 in. × 3 in. × 3 in. for the burn pan; and 118 kg (260 lb) of total waste, of which no more than 23 kg (50 lb) may be explosive, for the burn cage. Operation procedures will address the weighing or weight determination methods utilized to ensure limits are not exceeded. Concurrent operation of the OBUs will be prohibited. Each unit cannot be used more often than once every 24 hr. Thermal treatment will not be initiated prior to sunrise or if it cannot be assured that the treatment will be completed before sunset.

On-site weather monitoring and data recording systems will be used to back up the San Joaquin Valley Unified Air Pollution Control District's systems to decide if weather conditions are appropriate for a burn or detonation operation. The meteorological tower and data system indirectly provide assurance that thermal treatment activities will be safely performed with respect to atmospheric dispersal conditions. This system will partially mitigate both personnel and operational safety concerns.

In accordance with LLNL's administrative controls, the burning of explosives waste is not authorized when wind velocity is less than 8 km/hr (5 mph), greater than 32 km/hr (20 mph) or during electrical storms. The Site 300 ES&H Team uses an Atmospheric Potential Gradient System to predict the likelihood of a lightning strike. If a lightning alert is called during setup for waste treatment, all operations will cease. The firing circuits will be disconnected, shunted, grounded, and personnel will evacuate at least 381 m (1,250 ft) from the area or take shelter in a hardened bunker.

The chances of an accidental explosion will be minimized by strict administrative controls on the sources of ignition. No smoking, matches, or lighters will be permitted within the EWTF. Prior to any maintenance or construction operation on a facility containing explosives waste, the tasks will be reviewed and a Hazardous Work Permit will be issued. Explosives wastes will be removed prior to work where heat or spark-producing equipment or outside contractors are involved (LLNL, 1991). Open flames, smoking, cutting, welding, and sparks are prohibited at the treatment units when explosives are present. The EWTF units, including monitoring equipment, safety equipment, emergency response equipment, security devices, structural equipment, and operating equipment will be inspected on a routine basis. More details pertaining to these inspections and a sample of the inspection checklist are included in Section VI of the *Operational Plan for Site 300 Explosives Waste Treatment Facility* (LLNL and Radian, 1993b).

Cased explosive charges to be disposed of as waste at the EWTF will be evaluated on an individual basis. The distance traveled by fragments depends on both the net explosive weight (NEW) of the charge and the casing characteristics (thickness, weight, and material). An infinite number of combinations of these parameters could occur in future waste streams treated at the EWTF. Protection from fragments will be handled in the same manner as for explosives tests conducted at Site 300. The current B Division Site 300 FSP addresses considerations for shots with a high potential to generate fragments. The EWTF FSP will be used to determine if the cased explosive charge being considered for disposal can be detonated safely as far as fragment protection is concerned (the 159-kg [350-lb] limit will still be enforced). It will determine the fragment hazard for cased explosives using plots similar to those in the above-mentioned B Division FSP. These plots predict whether the fragments will stay within the designated muster radius. If they will not, then the muster radius must be increased, a shield must be built, or the item must be rejected for treatment.

Personnel access to the EWSF and EWTF will be limited according to the requirements of the *DOE Explosives Safety Manual* (DOE, 1994). Access to the EWTF during setup and treatment will be controlled by a muster system in accordance with Firing Area Access and Muster Control procedures specified in the B Division Site 300 FSP (LLNL, 1994a). The Central Control Point (a new muster system with a new control point will be completed and implemented prior to EWTF completion [LLNL, 1994a]) will provide a systematic means of controlling personnel access to the area of the EWTF when thermal treatment processes are being prepared or processed. OD operations will require a full area muster. This combined physical and administrative system directly limits personnel exposure to potential hazards associated with thermal treatment.

The CCTV will provide operators the ability to visually monitor thermal treatment operations at the open burn and open detonation areas. CCTV will be used to ensure that the treatment is completed. The workers will stay in the control bunker for an additional 30 min. If there is a question of whether to stay in the shelter of B845 for some additional period of time beyond procedural minimums, the individual shall use the CCTV to assess the safety of exiting. A period of 24 hr is allowed for the ash and the unit to cool before it is inspected by the Technician-in-Charge. When it has been determined that the unit and ash are completely cool (at ambient temperature) to the touch, then the ash can be removed and another batch of wastes can be treated.

Personnel Controls

All personnel handling explosives waste and actively participating in the thermal treatment operation will be trained and qualified in accordance with the LLNL *Health & Safety Manual* (LLNL, 1992). They shall wear protective clothing and appropriate gloves as specified in the safety procedure. LLNL-issued safety shoes or booties will be worn within the treatment compound. Although two fire extinguishers are required to be at the site during operations, personnel will not fight fires involving explosives or any fire that requires them to move toward actively burning explosives or explosives wastes.

Fire extinguishers will be available at specified locations to assure a rapid response to potential fires not involving explosives, contributing to both property protection and personnel safety. Personnel will be appropriately trained in the effective use of fire extinguishers.

3.4 Waste Confinement and Management Systems

After completion of thermal treatment, ash residual from the burn pan will be placed in containers and taken to the Site 300 Waste Accumulation Area.

The open burn cage will generate some ash residue. This residue will be handled in the same manner as above. Ash that is determined by analysis to be classifiable as hazardous will be disposed of by the normal HWM programs of the Laboratory.

Generally, the open detonation area will create a residue so fine as not to be recoverable as a waste stream. Detonations theoretically will create fine particulate matter that will be transported in the atmosphere a short distance prior to deposition on the Site 300 soil. There may be, on rare occasions, a small piece or pieces of undetonated explosives that have been ejected as missile fragment(s) from the treatment. If this occurs, the operators will follow safety procedure requirements to recover or dispose of any pieces.

Surface water from rainfall will be controlled to minimize the amount of water that can run onto and potentially contaminate the units. Water will be diverted from the units by site drainage systems.

3.4.1 Waste Management Criteria

No explosives wastes will be stored at the EWTF. Treated explosives waste residual ash can be removed from the treatment units after a 24-hr cooling period. The operator will examine the ash to verify whether treatment is complete or if additional treatment is required. Removal of ash also may be postponed due to adverse weather conditions (rain or high winds). If it has cooled sufficiently 2 hr after treatment, the burn pan cover will be positioned to protect the ash from rainfall and wind dispersion. The burn cage design also isolates and protects the ash from rainfall and wind. Based on these operational designs and procedures, no secondary containment is required.

Waste storage at B816 is described above in Section 3.3.2 and will meet LLNL program requirements.

3.5 Analysis of Normal Operations

This section describes the facility safety programs that assure safe operation; documents the analysis of hazards associated with normal operation; and details accident conditions.

3.5.1 Sources of Hazards from Normal Operations

Table 5 lists the possible sources of hazards that will be present in the operation of the storage and treatment facilities. This list was derived from those presented in the *Health & Safety Manual Supplement 6.06* (LLNL, 1991a).

Some of these hazards constitute common industrial hazards and will not be covered under the PSAR. This analysis will concentrate on those hazards unique to the EWTF and B816.

3.5.2 Analysis

The determination of the hazard classifications for B816 and the EWTF is based on DOE's criteria (DOE, 1987) and on the approach for chemical hazard classification currently employed at LLNL (LLNL, 1991a). This process of hazard identification is consistent with the requirements of 29 CFR 1910.119 (e)(2). An additional rigorous review will be required at the final design stage to develop and document the pre-startup reviews also required by DOE/LLNL and the OSHA Process Safety Management Standard. Possible hazardous events are reviewed using the list of energy sources in Table 7 and a review of the operations. These events are analyzed by a team of safety analysts to evaluate the hazards that may be detrimental to the worker, the general public, or the environment. Only credible scenarios are considered. Potential consequences to workers, the general public, and the environment are determined as if there were no mitigators in place. The worst consequence is compared with criteria set forth in Section 4.3 to determine the hazard classification. The hazard classification is not a statement of the risk of operating the facility and therefore does not take into account the active safety features. The effects of those features will be included in the risk analysis, Section 4.4.

Mitigators are then chosen to reduce the consequences. Analysis methods are used to determine the consequences of the hazards after application of controls and mitigators. For each event, the causes, preventative features, methods of detection, mitigation features, and consequences are identified. The results of these events are summarized in a hazards characterization table (Table 8) and each type of event is discussed below.

Building 816 Fire. Events or accidents were postulated for B816 and the treatment facilities. B816 will be used to store explosives-contaminated waste. Because this waste (Form 4) is considered reactive, weight limits will be determined in the final design stage using the previously described Quantity-Distance calculation method. The waste is expected to contain very small NEWs and so, considered alone, this waste poses only a fire hazard. However, it will be situated in a five-magazine circle that will be used to store the other three waste forms, including Class/Division 1.1 explosives. To determine the hazards posed to personnel at B816 from external facilities, an accidental detonation at one of the magazines (M1–M5) would have to be considered. This will be included in the safety analysis for magazine operations, to be done later.

Accidental Detonations. The worst accident for the EWTF would be a detonation, because in all accident scenarios involving detonations, fatalities may be a possible consequence. Detonations can be caused by lightning, electrical or electro-static discharge, shock, earthquake, or human error. An incompatible mix of wastes, dropping explosives, smoking, and use of spark-producing equipment near explosives are examples of human error.

In analyzing the impact of accidents in the waste treatment facilities, it must be remembered that controlled operations of explosives burns and detonations are normal. Therefore, only an abnormal or unexpected explosion would constitute an accident.

Furthermore, the treatment facilities and operational procedures have been designed and developed so that the consequences of an accident should be minimal if procedures are adhered to. In all cases, facility safety procedures developed using the *DOE Explosives Safety Manual* (DOE, 1994a) limit the number of personnel who may be present during operations of the OBUs or ODU to minimize injuries or fatalities as a consequence of an abnormal detonation. At least two but not more than three operators must be present for an open detonation or open burning operation. If there are three operators, a maximum of two observers may be present. If there are only two operators, only one observer may be present through the entire operation. All facilities are to be inspected on a regular schedule that will be included in the FSP. The following paragraphs describe circumstances in which accidental detonations could occur.

An accidental explosion (detonation or deflagration) could occur in the open burn area due to an incompatible mix of wastes placed in the pan, inadequate characterization of a waste, confinement of the burn, or from inadvertently placing an object in the pan that can act as a detonator. (This latter event happened in B829 at Site 300, the existing burn pit in 1981. Glass vials containing explosives were placed along the edges to burn out the explosive. It was not realized that these would act as natural detonators.) There can also be unknown ignition sources in the pit, such as a warm surface from a previous burn. An accidental explosion can result in injuries or fatalities and the loss of property and equipment. Administrative controls serve to prevent and mitigate this event by prohibiting containers that confine the waste and limiting the quantity of explosives in any single burn. All treatment units are inspected before and after each use (burn or detonation) to ensure that they are cool and free of debris.

In the open detonation area, a premature detonation would be considered an accident. This event could occur if a detonator or detonators go off too early or because of human error. Examples of human error include use of the wrong type of detonator and dropping a piece of explosive.

Training of personnel and restrictions on configurations of explosives and detonators included in the *Site 300 Safety and Operational Manual* help to prevent such accidents from occurring. Personnel who handle explosives will be qualified explosives handlers trained in accordance with the *DOE Explosives Safety Manual* (DOE, 1994a) and the LLNL *Health & Safety Manual*, Chapter 24 (LLNL, 1992).

Other Hazards

<u>Grass Fire</u>. The OBUs and ODU create the potential for grass fires from blowing embers or hot fragments of undetonated explosives. Depending on the extent of a grass fire, there could be loss of property or injury to personnel. Ways of preventing and mitigating these consequences are to reduce the ignition sources and contain the spread of fires. Prevention is achieved through design features such as the choice of a sheltered site location and using a remotely controlled burn pan cover (to keep hot ash from blowing after the burn.) Administrative controls will limit burns to proper weather conditions and dictate that the area within 61 m (200 ft) of the treatment compound will

be kept free of dry grass, leaves, paper, and other extraneous combustible materials. Firebreaks must be maintained in the surrounding area. Ignition sources such as cigarettes and lighters are strictly prohibited beyond the personnel control point. The LLNL Fire Department and mutual aid agreements with local fire departments also serve to mitigate the consequences of a grass fire. These mitigation features also lessen the consequences of grass fires caused by other facilities in the area and natural phenomena.

<u>Dispersal or Spills of Wastes.</u> Some of the explosives waste to be stored and/or treated can be irritating to eyes, skin, and respiratory systems. During preparation of the units, workers could come into contact with these irritating compounds during spills at either the storage or treatment facilities. Spills may occur due to human error or container failure. For this reason, workers will be trained and will wear protective coveralls and gloves when handling chemicals listed as requiring gloves in Appendix B of the B829 OSP (LLNL, 1995). Spilled waste may also create an explosion hazard. Safety straps and training are used to prevent spills.

<u>Products of Combustion</u>. Some of the explosives waste products of combustion may be toxic. For this reason the OBUs and the ODU have been placed far from other operations and the general public. Additionally, burns and detonations are performed only when atmospheric conditions are such that the products are adequately dispersed before reaching the general population. For the most toxic of these products (shown in Table 6), the atmospheric dispersion model EPIcode was used to predict exposure values for off-site personnel.

<u>Untreated Explosives Ejecta</u>. On rare occasions, a piece or pieces of untreated explosive may be ejected from the treatment unit. Administrative controls seek to prevent this occurrence by prohibiting the burning of encased explosives (unless specific approval is obtained) and limiting the configuration (depth) of explosives placed on the OBU. A pea gravel base on the detonation unit helps to absorb some of the energy that is directed downward and helps to lessen ejecta and their energy. Incompletely treated pieces of explosive could cause death, injury, or property damage if mishandled. Currently, the OSP for B829 specifies that such untreated explosives ejecta, should they occur, be detonated in place if unsafe to handle, using additional explosive material if necessary to ensure detonation. An equivalent procedure will apply at the new EWTF for those rare occurrences where small untreated explosives pieces are ejected from the treatment unit.

<u>Leak of Propane Tank</u>. A projectile ejected from the open burn area could puncture the propane tank, or a failure in the tank piping or valves could cause a leak from the tank. This leak could result in a fire or an explosion and thus injure people or cause loss of property. This hazard is mitigated by the design, which creates distance between the tank and the burn area and by the placement of an earthen barricade between them. Routine inspections of the tank piping and valving also help to prevent a leak.

<u>Noise</u>. Noise can cause a hearing loss on the part of workers and is a common source of public complaints. Since noise is an inherent characteristic of explosions, it cannot be eliminated, but the choice of a remote location serves to mitigate the consequences to the general public. Site 300 also has computer modeling capability that can be used to prevent the occurrence of focusing shock waves by limiting the weight of explosives used according to the weather conditions. During operations, workers take shelter in the control bunker that is designed to prevent damage from the blast wave as well as mitigate high noise levels. Workers' hearing is medically monitored and, where necessary, Hearing Conservation Programs are implemented including the use of personal protective equipment, annual training, and limiting the workers' exposure.

<u>Failure of the Muster Control Procedures.</u> The presence of personnel within the area defined for muster control creates the possibility of injury or death during otherwise normal open detonation operations. The manning of observation points helps to prevent this. All personnel visiting or working at Site 300 must be trained in proper muster control procedures.

4. Accident Analysis

4.1 Abnormal Operations

Possible malfunctions of systems can occur that could result in a hazard. In the open burn area, the lid that is to be placed over the table 2 hr after the burn could malfunction either because of a mechanical failure or operator error from the B845 location. This occurrence could cause a partial confinement of any explosives left from the treatment, causing either an incomplete treatment or, at worst, a detonation. A premature ignition in the open burn area could also occur, resulting in a flash fire or a detonation that could cause severe injuries or fatalities. Another abnormal operation would be a premature detonation in the open detonation area while the unit is at some stage of preparation for a treatment and contains some or all of the intended explosives. There would be a high likelihood that personnel would not be in the protective bunker and could be injured or killed. Any explosives not yet placed in the unit would be at risk to detonate as well. A failure of the personnel access controls, both in the storage area and treatment areas, would mean additional injuries/fatalities during accident conditions or normal treatment.

Though these postulated incidents may occur as a result of abnormal operations, the consequences fall within the bounds of the accident analysis.

4.2 Accidents

The nature of explosions is such that two results of an accident must be analyzed. The first and most hazardous concern involves the effects of the blast wave, fragments, and thermal flux. Second is the effects of potential inhalation of toxic products of combustion. The analysis of an accidental explosion therefore includes determination of these potential hazards. While the products of combustion from explosives are considered to be similar for burning as for detonation, the dispersion will be different because the mechanism of release is different. A burn is best modeled as a point source that lasts for a specified length of time while a detonation is an area source that is nearly instantaneous.

4.2.1 Detonation Effects

Different explosives compounds have different energy/mass values. One way to compare compounds is to compare them to TNT (by way of a TNT equivalence, a dimensionless ratio). The highest TNT equivalent found among the compounds in use at Site 300 is 1.3. Of the three treatment units, the open detonation pad has the highest weight limit of explosives allowed, 159 kg (350 lb). The most energetic explosion that could credibly occur in the treatment area would be the case of an open detonation pad loaded with 159 kg (350 lb) of any of the explosives having a TNT equivalence of 1.3, detonated prematurely or remotely detonated while someone who had broken muster procedures was in the area. If the detonation occurred prematurely, the effect to handlers in the immediate area would probably be death, but to a person somewhere within the muster distance, the effect will depend on where they are relative to the explosion. The Quantity-Distance K-factors can be used to predict the injuries personnel would sustain due to overpressures. Injuries from fragmentation will depend on what the treatment consisted of (possibly encased explosives), what equipment was in immediate area, etc. Because the probability of being struck by fragments is difficult to predict, conservatism is built into the values of *DOD Ammunition and Explosives Safety Standards* (DOD,1992), used for Q-D calculations when fragment hazards are thought to exist. Thermal flux effects can cause burns to individuals, particularly in the case of a flash fire (in the case of a detonation, overpressure and fragmentation pose greater hazards). For this reason, thermal treatment is done remotely and workers wear appropriate clothing, as described earlier.

4.2.2 Products Dispersion Effects

During an accidental detonation or explosives fire, overpressure, fragment, and thermal flux hazards are the most critical to individuals inside the 381-m (1,250-ft) hazard zone. But during any of the treatments (normal or accident conditions), toxic by-products of combustion / detonation are given off and dispersed according to atmospheric conditions. As a part of the hazard classification portion of this PSAR, those emissions must be looked at as to their effects on and off site. In the following analysis, several air dispersion principles are demonstrated:

(1) Explosions are extremely efficient disposal mechanisms, as they thermally decompose large macromolecules to smaller molecular weight products.

(2) An explosion simultaneously harnesses and releases the previously hazardous stored energy, converts reactants instantaneously, and disperses the resulting gaseous products. A significant proportion of these hot by-products then rise due to buoyancy although a small fraction (0.04) is released at ground level (Church, 1969).

To determine the gaseous by-products of a fire and an explosion, screening of the explosive waste streams received by the EWTF was performed in Section 3 of this document to identify the worst-case accident source term with respect to a typical waste stream. Based on the products of decomposition presented in Ornellas (1982), the Environmental Assessments for HEAF (DOE, 1989b), EWSF (LLNL, 1994b), and EWTF (DOE, 1994b), LX-04-01 was determined to be the worst-case starting product. The consequence analysis of the air dispersion assumes that 100 percent of the fluorine from the Viton binder converts to hydrogen fluoride (HF).

It can be shown that, all other parameters being equal, an unconfined explosion would in every case result in higher airborne concentrations of hydrogen fluoride at the receptor of interest (the nearest fence line) than would be expected to result from the same quantities of explosives that are burned. The following analysis provides a clear cut example.

Several worst-case assumptions are made:

- for the fire's smallest radius: 1 m.
- for the most conservative thermal plume rise: 11 m (based on the method by Gouveia [1989]).
- and the largest possible burnable LX-04-01 inventory: 350 lb.

The variables used in the air dispersion modeling are listed in Table 9.

The assumptions for the worst-case analysis suggest why the modeling of a release of the equivalent mass of explosives which explodes (rather than burns), is modeled over a considerably larger area. This analysis shows that a 69-m (226-ft) radius, based on the detonation of 159 kg (350 lb) of LX-04-01(430 lb of TNT equivalent) will result in higher airborne concentrations of hydrogen fluoride (HF) at the nearest off-site receptor of interest. The receptor of interest in this case is 1,900 m (6,225 ft) downwind from the EWTF. For the purposes of this worst-case analysis, one can assume that the wind blows in the direction of the nearest off-site receptor. We assume a burn under worst-case meteorological conditions (7.5 m/s wind speed) to assess the worst-case consequences from an airborne release of thermal decomposition products.

The Gaussian-dispersion-based equations (Salazar, 1992) below estimate the airborne concentrations of hydrogen fluoride at 1,900 m (6,225 ft) and therefore compare the dispersion of products from a worst-case burn to that of a worst-case explosion given the above assumptions:

The source term, Imax, is derived from the quantity of LX-04-01 involved (159 kg [350 lb]) times the maximum value for HF in kg/kg HE given in Table 6 (0.104 kg HF/kg LX-04). This gives an Imax of 16.5 kg (36.5 lb) of HF.

Given that, for the modeling of the airborne concentration of a fire:

$$\text{Imax}_1 * 10^6 * (X/Q)_1/t_1 = \text{concentration of HF in air, in mg/m}^3$$

And, given that for an explosion:

$$\text{Imax}_2 * 0.04 * 10^6 * (X/Q)_2/t_2 = \text{concentration of HF in air, in mg/m}^3.$$

Where

Imax= the mass of HF inventory in kg

10^6= unit conversion factor, mg/kg

$$X/Q = \text{atmospheric dispersion, s}/\text{m}^3$$

$$t = \text{Release duration in seconds.}$$

Values for these parameters for the case of a burn and an explosion are shown in Table 10.

Gaussian plume dispersion estimates of airborne concentrations at the nearest off-site receptor (1,900 m [6,225 ft]):

$$\text{Imax} * \text{RF} * 10^6 \, (X/Q) \; / \; t = [\text{HF}]$$

Fire:

$$(16.5 \text{ kg} * 10^6 * 1.1 \text{ x}10^{-5}) / 600 = 0.29 \text{ mg}/\text{m}^3$$

Explosion:

For the contribution to concentration from ground level:

$$[(16.5 * 0.04) * 10^6 * 1.8 \times 10^{-6})] / 1 = 1.2 \text{ mg}/\text{m}^3$$

For the contribution to concentration for up to 69 m in height:

$$[(16.5 * 0.16) * 10^6 * 6.9 \times 10^{-8}] / 1 = 0.2 \text{mg}/\text{m}^3$$

Where: For the explosion, the release fraction 0.04 is the fraction of the source term that is released from ground level, and 0.16 is the fraction of the source term that is released at the effective height of 69 m (226 ft) (Church, 1969).

Table 11 shows the results of these calculations of the concentrations and conditions of interest and how they compare to the Emergency Response Planning Guide (ERPG) levels.

4.3 Hazard Classification

As a single building, B816 would have a low hazard classification. The hazard it poses is that of a fire. Even though the waste stored there may be anticipated to burn more vigorously than typical laboratory waste, consequences would be limited to property damage and perhaps minor personnel injuries. Effects (on site and off site) from a detonation of a magazine will be considered when the hazard classification for the EWSF's magazines is done along with all other Site 300 magazines.

Without doubt the most significant hazard derived from the handling of explosive wastes at the EWTF would involve the hazards to the HE handlers, in the unlikely event of an unintentional detonation or deflagration during setup for waste treatment.

Consequences could involve fatalities for those two to three individuals directly involved in the operation and any others exposed to detonation or deflagration. Another case could involve observers or transients mistakenly in the danger zone during muster, or personnel at nearby buildings, but not under protective shelter, who could be injured or killed. Off-site consequences from the blast wave would be much less severe due to the remote location of the treatment units and may involve broken windows if one assumes worst-case atmospheric conditions that could consequently induce a focusing of the overpressure towards Tracy (DOE, 1992).

DOE Order 5481.1B, *Safety Analysis and Review System*, defines a moderate hazard facility to be one with considerable potential for on-site impacts to people or the environment, but at most only minor off-site impacts. Because there is the potential to cause severe injuries or fatalities to LLNL's explosives handlers and minimal off-site impact as a result of unintended detonations, a moderate hazard classification is assigned for the EWTF and a low hazard classification of B816 as a single building.

The results of worst-case airborne concentrations (Section 4.2.2) are compared to several commonly accepted dose response values in Table 12. The consequences to a worker at 100 m (328 ft) from the worst-case accidental burn (assuming that the HE does not detonate) would be negligible because the airborne concentration of HF falls below the ERPG-1 and is estimated to last approximately 10 min, well below the 1 hr ERPG specified duration. In fact this exposure falls below the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value-Ceiling (TLV-C), of 2.6 mg/m^3, the concentration that should not be exceeded during any part of the working day.

Assuming that an explosion occurs, an individual at the nearest fence line during a worst-case explosion at most would experience mild reversible health effects and irritation of the eyes, nose, mouth, and respiratory system due to dispersion of toxic products of detonation. Therefore, based strictly on the airborne exposures resulting from an accidental release this facility would be classified as a low-hazard facility for safety analysis purposes.

4.4 Risk Characterization

The consequences of, and probability estimates for, the scenarios postulated in Table 8 which represent the credible accidents associated with B816 and the EWTF, but not found in standard industrial activities, were determined using the information contained in Tables 13 and 14. For each of the scenarios, the consequences stated in Table 8 were evaluated against the general description of the consequences in Table 13 to determine the appropriate consequence level. Likewise, the expected probability of the scenario was determined from review of the ranges stated in Table 14. Determinations from these two tables are then applied to the matrix of Figure 9 to obtain the semi-quantitative risk designation. This method of risk determination is described in DOE/SAN *Management Directive 5481.1A* (DOE, 1989a) and LLNL *Health & Safety Manual Supplement 6.06*. (LLNL, 1991a).

Table 15 depicts the results of the determinations for the ten scenarios selected. Two scenarios have a negligible risk value and eight of the scenarios are determined to have low-risk valuation. According to DOE/SAN *Management Directive 5481.1A* (DOE, 1989a) and LLNL *Health & Safety Manual Supplement 6.06* (LLNL, 1991a) guidance, these determined risk values are acceptable, meeting or exceeding the desired objectives for operation of a moderate-hazard, non-nuclear, DOE facility.

5. Conduct of Operations and Operational Safety Requirements

5.1 Conduct of Operations

The EWTF will operate under the *Operational Plan for Site 300 Explosive Waste Treatment Facility* (LLNL and Radian, 1993b) which was submitted as part of the RCRA permitting process for the facility. The following sections provide very brief, pertinent excerpts of some of the plan.

5.1.1 Organizing Structure

HWM is responsible for the facility. The B Division Site 300 organization is responsible for the firing area in which EWTF is sited. The operations of EWTF will conform to the overall managerial controls and system monitoring processes established for the safe operation of Site 300.

5.1.2 Training

Only qualified Explosives Waste Treatment Facility personnel (as specified in Section 7 of the operational plan [LLNL and Radian,1993b] and Supplement 24.03 of the *Health & Safety Manual* [LLNL, 1992]) shall transport, move, assemble, or handle explosive waste. Specific training prerequisites must be met to qualify as an Explosives Handler.

5.1.3 Inspection and Testing Program

As a part of the compliance program for hazardous materials regulations, routine inspections and testing will be performed. Procedures for routine inspection and operational surveillance will be developed, as appropriate, to assure the operational integrity of the EWTF equipment and facilities.

5.1.4 Configuration Control

Equipment configuration will be controlled by procedures of the Facilities Engineering Department. These procedural controls will meet the requirements of 29 CFR 1910.119.

5.1.5 Procedures

Operations at the EWTF will be performed by trained personnel in strict adherence to written operational procedures.

5.1.6 Safety Review System

As stated above, the facilities and equipment will be subject to design control procedures, which include configuration control elements. Procedures will be subject to administrative controls that maintain procedural conformity to system configuration. Both procedural changes and equipment changes will be subject to formal review to assure that the authorization basis of the facility is maintained in conformance with DOE 5480.21 (*Unreviewed Safety Questions*) requirements.

5.1.7 Emergency Planning

Section 8 of the operational plan (LLNL and Radian, 1993b) contains a discussion of the contingency plan and emergency procedures. The entire EWTF contingency plan is included as Appendix VII-A of the plan document.

5.1.8 Record Keeping and Reporting

The steward / operator will maintain copies of all records of explosives waste management at the EWTF until facility closure. These records will be furnished, when appropriate, upon request by authorized representatives of regulatory agencies.

5.2 Operational Safety Requirements Guidance

5.2.1 Safety Limits and Limiting System Setting

Safety limits for the EWTF will be established by the Explosives Safety Engineer. Safety Limits shall be set forth in the FSP and any deviation above the limit must be specifically authorized in an OSP.

5.2.2 Limiting Conditions for Operation

Operations of the EWTF will be strictly limited to 159 kg (350 lb) NEW for detonation operations, 68 kg (150 lb) NEW for the burn pan, or 23 kg (50 lb) NEW for the burn cage. Muster controls and personnel controls described in Chapter 3 will be strictly adhered to.

B816 will be limited to 17 kg (45 lb) of total NEW inventory (composite weight of all waste classes).

5.2.3 Surveillance Requirement

All facilities and equipment will have appropriate surveillance procedures defined and surveillance intervals established.

5.2.4 Administrative Requirements

Administrative systems and controls shall meet all applicable state and federal laws and DOE requirements. The requirements of 29 CFR 1910 will apply.

6. Quality Assurance

This section reports the quality assurance objectives for the EWTF and EWSF. Methods of compliance with DOE Order 5700.6C are presented here.

6.1 Management

6.1.1 Program

The *Quality Assurance Program*, (LLNL, 1994c) describes LLNL's Quality Assurance Program and identifies the QA requirements applicable to all of the Laboratory's activities. The program is based on the quality principles of DOE Order 5700.6C. The objectives of the LLNL's QA Program are to assure the following:

a. Management provides planning organization, direction, and support to achieve programmatic goals.

b. Line organizations achieve quality programmatic objectives.

c. Evidence of performance is documented and maintained.

d. Performance is reviewed and evaluated.

e. Continuous improvement is emphasized.

f. Corrective and improvement actions are effectively implemented.

An Engineering Directorate Draft Quality Assurance Plan is in review. The organization and responsibilities are covered in Sections 3.0 and 5.0 respectively. The Plan mirrors the criterion of DOE Order 5700.6C. It requires that an Activity Level Quality Assurance Plan be developed for high-level risk activities and for those mid-level risk activities specified by the Deputy Associate Director or Division Leader.

Chapter 2 of the *Health & Safety Manual* (LLNL, 1992) requires an Operational Readiness Review (ORR) or Management Prestart Review (MPR) before startup of new and modified nuclear facilities. These are consistent with the intent of 29 CFR 1910.119 requirements. The review process will determine that the facility, hardware, personnel, and procedures are in a collective state of readiness.

6.1.2 Personnel Training and Qualification

The main purpose of the LLNL Training Program is to provide appropriate instructional support to assist employees in developing and maintaining competencies to successfully execute their work assignments. The LLNL Training Program Manual (LLNL, 1991b) provides guidance for developing and managing individual directorate training programs, including the following:

- Determination of job categories, specific qualification requirements, and training requirements and responsibilities.
- Documentation of training information.
- Qualification of course materials and instructors.
- Evaluation of the training program.

The draft Plan states that the personnel are to be properly trained and qualified to perform their assignments in accordance with both the LLNL Training Program Manual and the Engineering Implementation Plan for the LLNL Training Program.

6.1.3 Quality Improvement

Section 7.0 of the draft Plan discusses the concept of continuous improvement. Items and processes that do not meet established requirements are to be identified, documented, analyzed, and corrected or, when appropriate, locked-out or suspended.

Section 1.06 and Supplement 1.11 of the *Health & Safety Manual* (LLNL, 1992) give any LLNL employee the right to order any activity stopped immediately if, in the employee's judgment, the procedure or circumstance represents an imminent, high-risk threat to human safety or health. The draft Plan also states that every individual is responsible for initiating appropriate steps to discontinue any operation or practice that could lead to injury, illness, unacceptable property or environmental damage, or jeopardize programmatic objectives. A process of analysis of information to identify trends and prevent occurrence or recurrence of problems should be identified.

6.1.4 Documents and Records

The draft Plan indicates that written safety procedures are to be developed and appropriately controlled to govern work processes prescribed in the LLNL *Health & Safety Manual* (LLNL, 1992). Any activity-specific procedures developed to satisfy the requirements of this criterion should include descriptions of processes for (a) preparation, approval, and revision of procedures; (b) document issuance and use; and (c) record identification, retention, and retrievability.

6.2 Performance

6.2.1 Work Processes

Chapter 2 of the *Health & Safety Manual* (LLNL, 1992) prescribes the process for planning, authorizing, and accomplishing work under controlled conditions. Chapter 2 of the manual also provides guidance for developing, approving, and disseminating safety procedures and instructions and for monitoring ongoing activities and related information to ensure that the desired quality is being achieved.

Section 7.0 of the draft Plan prescribes that work shall be performed using approved instructions and procedures.

The level of effort expended by LLNL to track an item by its unique physical or chemical characteristics is directly proportional to the importance of the item's prescribed use. Controls are in place that require a unique serial identification number and supporting documentation to ensure that only correct and accepted items are used and installed. This documentation contains all the information necessary to identify, control, and maintain the specific item to ensure appropriate traceability.

The handling, storage, and shipping of items are controlled to prevent damage or loss and to minimize their deterioration. Handling, storage, and shipping are conducted in accordance with established work and inspection instructions, drawings, specifications, shipment instructions, subcontracts or purchase orders, or other documents that prescribe and control these activities.

6.2.2 Design

All LLNL equipment and facilities are designed and constructed to provide a safe work environment. Departments that design, assemble, or construct facilities or equipment follow all prescribed codes and standards, analyze their projects for all credible hazards, and incorporate all reasonable controls (LLNL, 1991b).

Section 7.0 of the draft Plan describes the design control process.

6.2.3 Procurement

LLNL personnel are to adhere to the established institutional procurement system and processes to ensure that technical goals are achieved, all applicable federal and state procurement regulations are satisfied, and Laboratory procurement policies are met.

Items are procured in accordance with approved procedures to ensure a systematic approach to the procurement process. Procurement specifications include quality control requirements, acceptance methods/criteria, and the documentation furnished by the vendor. The procurement process provides for the integration of procurement documents; preparation, review, and change control; selection of procurement sources; bid evaluation and award; verification (surveillance, inspection, or audit) activities; acceptance criteria; and identification, retention, and delivery of required documents and records.

Vendor evaluations are performed and documented to ensure that the vendors operate under an adequate system of quality control for the specified items being procured. Purchase specifications require suppliers to have a QA program consistent with the requirements of each procurement.

6.2.4 Inspection and Acceptance Testing

Section 7.0 of the draft Plan indicates that inspection and acceptance testing of specified items and processes shall be conducted using established performance and acceptance criteria. This requirement applies to items and processes that have already been tested for feasibility and that have been defined to require formal inspection. Readiness reviews generally pertain to the acceptance of an entire system.

When inspection or acceptance testing involves Measurement and Test Equipment (M&TE), the equipment is to be properly calibrated and maintained. The required accuracy of M&TE should be specified for each application.

6.3 Assessment

6.3.1 Management Assessment

Engineering's ES&H Self-Assessment Plan describes the directorate's program for evaluating the success of its ES&H program and identifying conditions requiring corrective action. In addition to ES&H concerns, management self-assessments are intended to evaluate customer and staff member perceptions relative to (a) the mission and strategic objectives of the organization, (b) the degree to which programmatic expectations are being met, and (c) opportunities for improving the quality of deliverables and cost effectiveness.

6.3.2 Independent Assessment

The draft Plan indicates that specific independent assessments shall be conducted to evaluate the effectiveness of the QA system and to promote quality and process improvement. Activity-specific independent assessments will vary in format and frequency depending upon the size, scope, complexity, and risks associated with an activity.

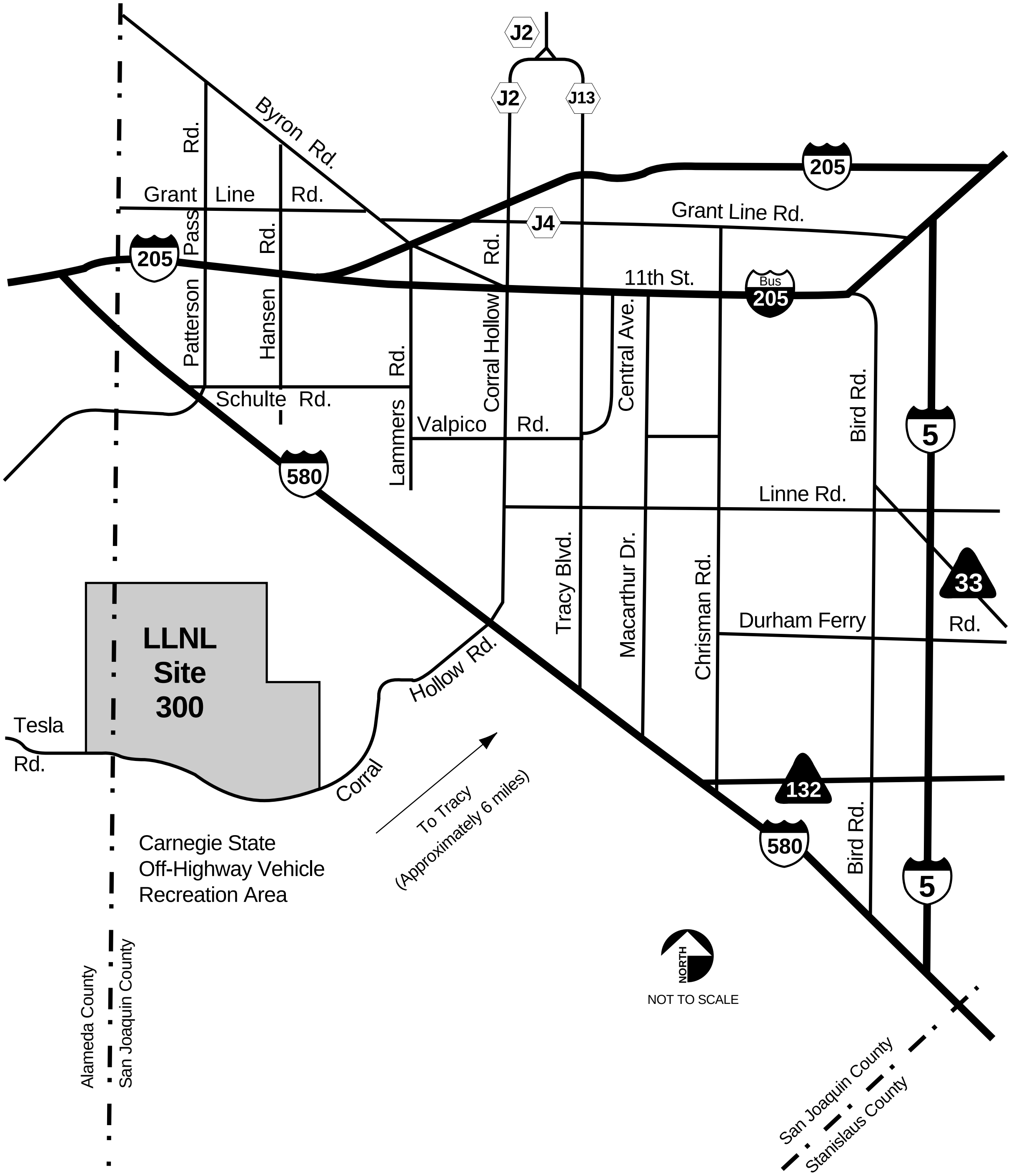

Figure 1. Location of Site 300

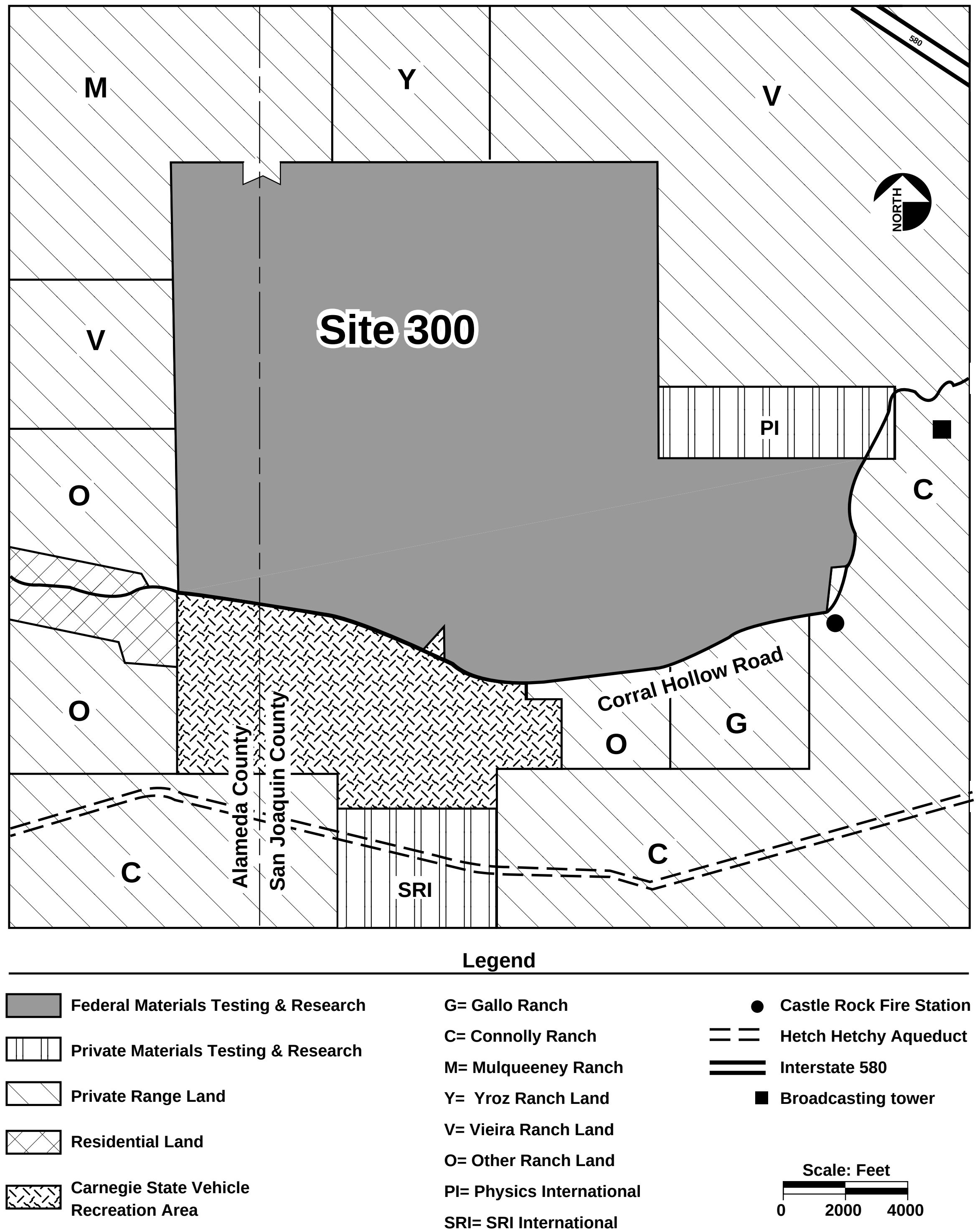

Figure 2. Land Use Surrounding Site 300

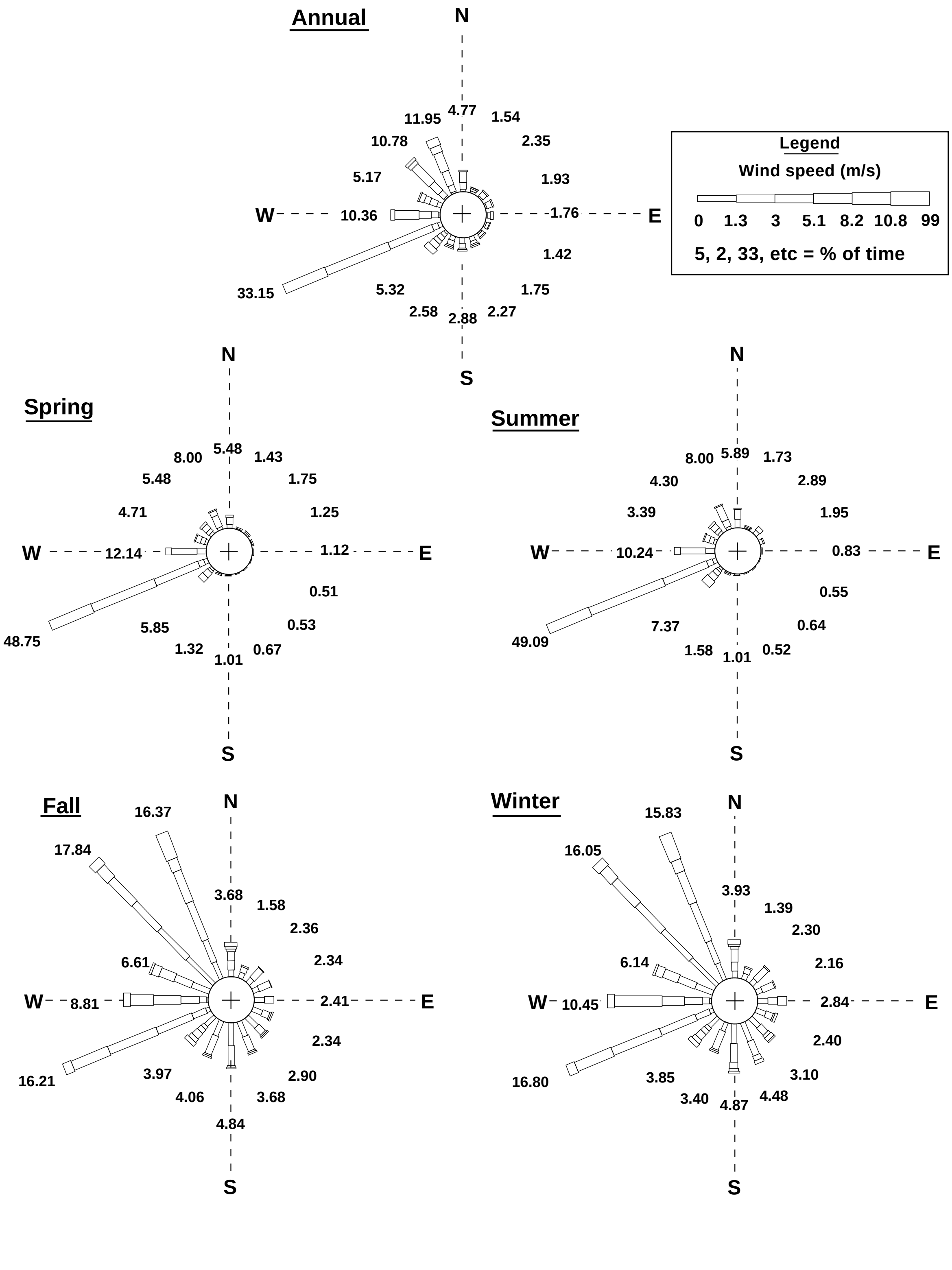

Figure 3. Annual and Seasonal Wind Roses for Site 300 for 1986–1990

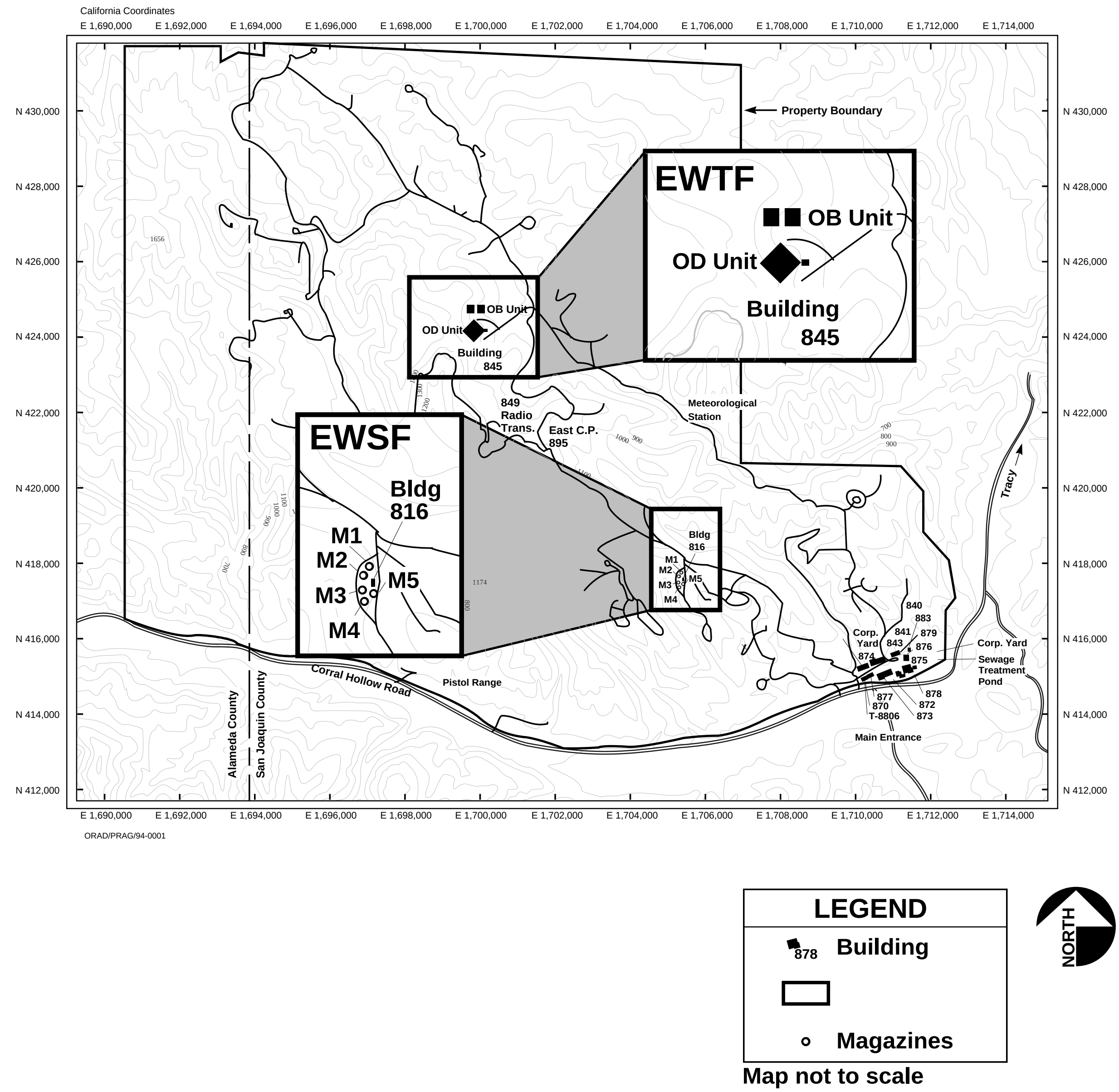

Figure 4. Detail of the EWTF and EWSF

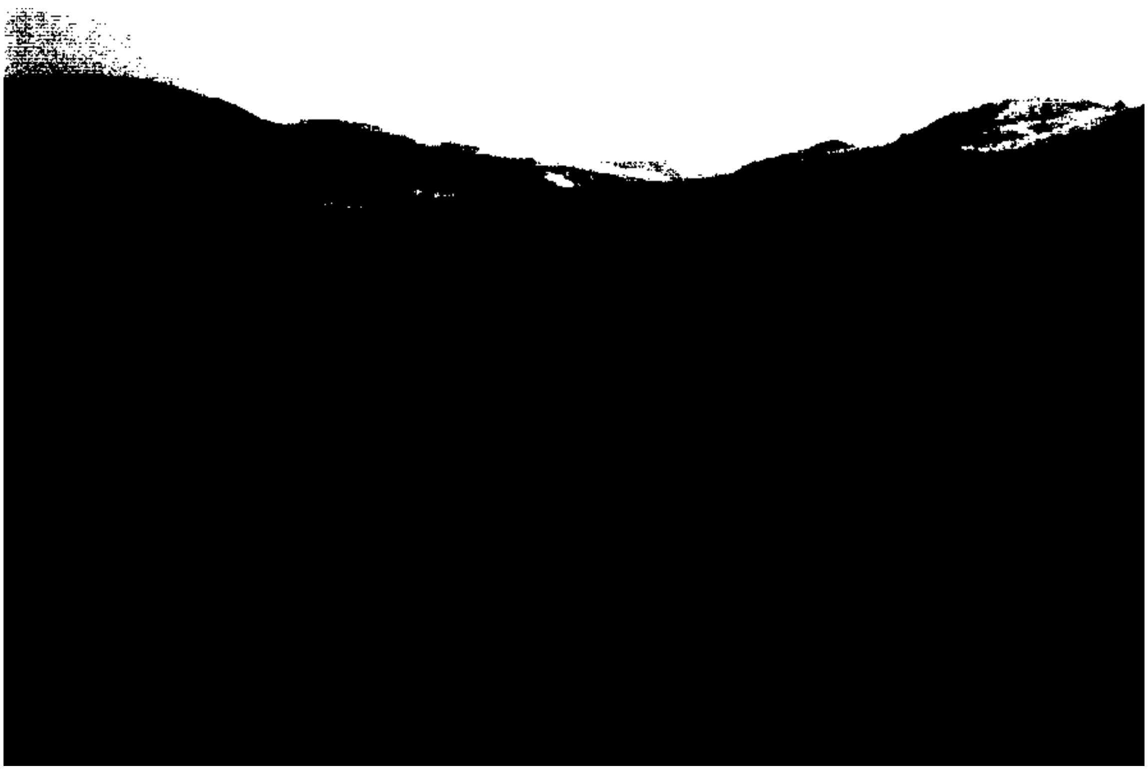

Figure 5. Proposed OBU Location, Looking Southeast

Figure 6. View of B845 and Proposed Location of ODU Area

Figure 7. View of B845 Control Bunker, Located Below and Downgradient of Proposed ODU Area

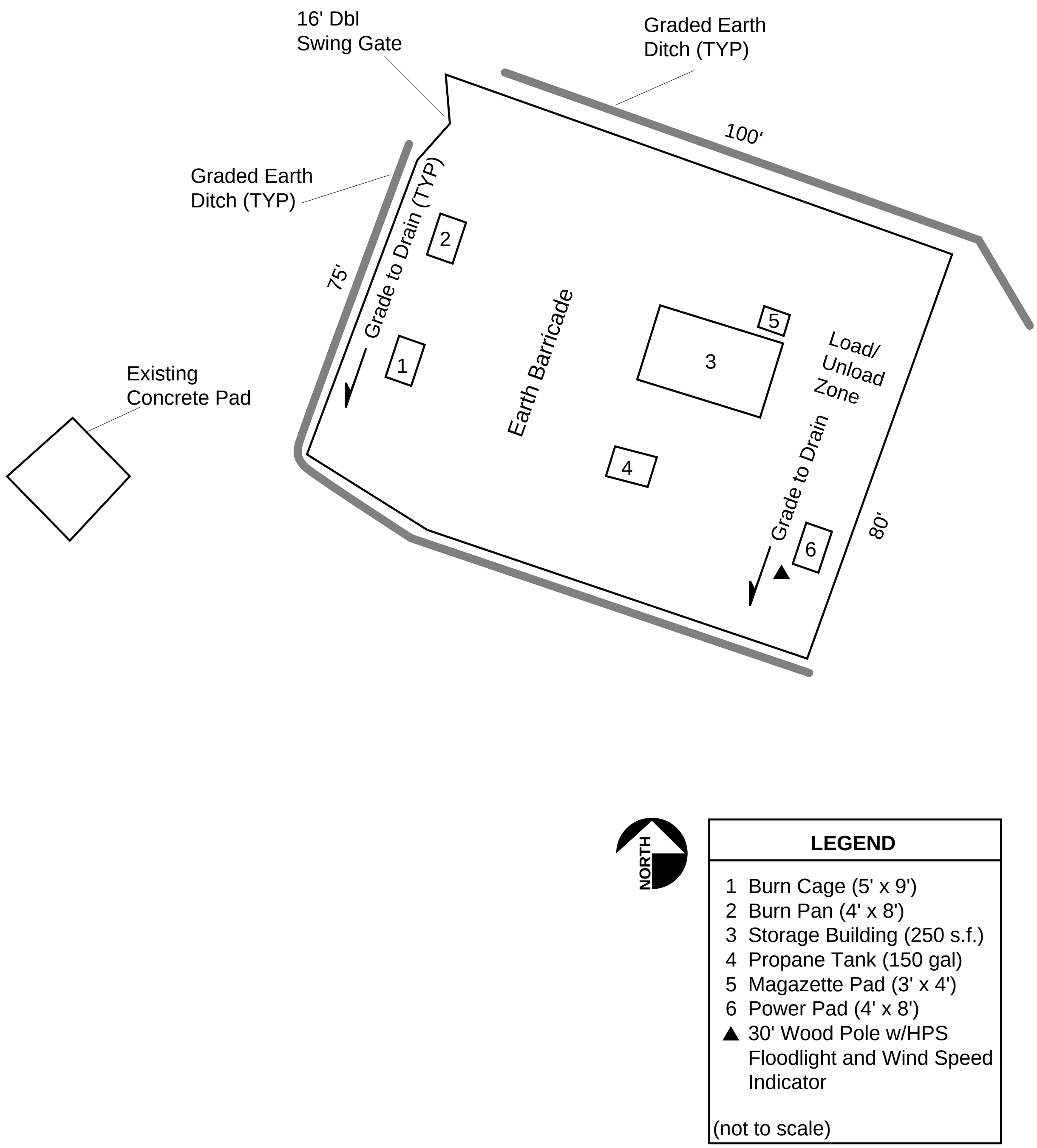

Figure 8. OBU Plot Plan

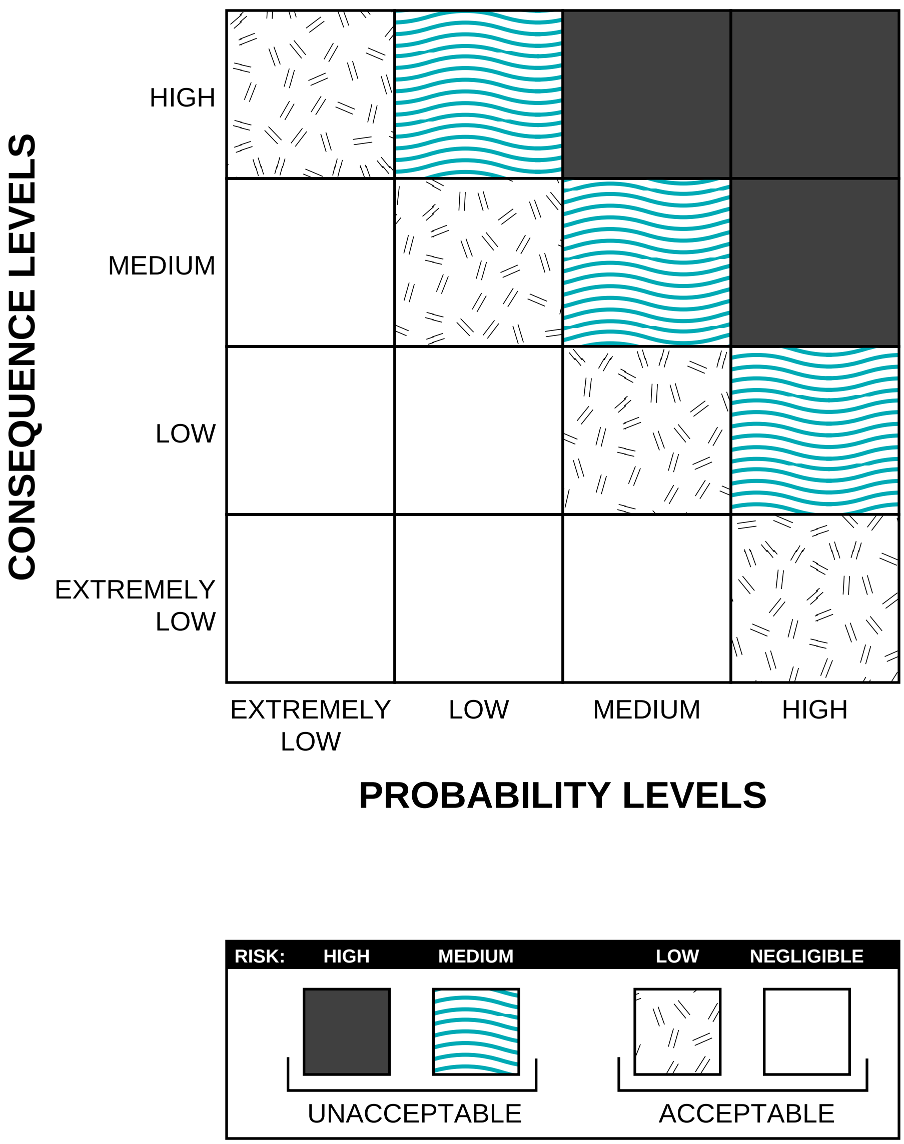

Figure 9. Risk Matrix

Table 1. Facility Design Standards

Facility Element	Design Standard	Rationale
electrical wiring	National Electric Code, National Electric Manufacturer's Assoc., Institute of Electrical & Electronics Engineers, Insulated Power Cable Engineer's Association	control electrical shock, and electrical excursion currents
fire loading, fuel & ignition sources	National Fire Code	fire protection and suppression
building structure	Uniform Building Code (new buildings only)	structural safety
burn pan unit	American Welding Society, American Society of Testing & Materials, American Society of Mechanical Engineers	steel vessel integrity, reliability
safety showers/eyewash stations	Uniform Mech & Plumbing Code, American Water Works Association	reliability of safety showers
detonation pad	DOE Explosives Safety Manual, 29 CFR 1910.119, DOD 6055.9-STD, ANSI Z358.1	personnel safety, property protection
propane tank	NFPA, American Society of Mechanical Engineers, Compressed Gas Institute	compressed gas safety, fire safety
bunker	TM5-1300	blast and fragment protection

Table 2. Level of Protection Standards

Protection Class	Protection Criteria
Class IV	- Provide protection of fire hazard effects • by hazard class / division 1.3 above ground-magazine distance separation, or • design to contain accident effects - Sited and designed as acceptors rather than donors
Class III	- Provide protection from explosion propagation between buildings located at intraline or magazine distance
Class II	- In addition to Class III, design shall prevent fatalities and severe injury to personnel in occupied areas (other than bay of occurrence) and personnel shall not be exposed to: • overpressures ≥ 103 kPa (15 psi) maximal effective pressure (from TM5-1300 [threshold pressure for eardrum rupture is 34 kPa, and 1 / 2 of threshold pressure for lung damage is 100 kPa]) • structural collapse • acceptor area generated missiles (fragments) > 58 ft-lb impact energy
Class I	- In addition to Class II, provide protection to prevent serious injury to personnel - Prevention is satisfied where personnel will not be exposed to: • overpressure > 34 kPa (5 psi) maximal effective pressure and <u>should not</u> exceed 16 kPa (2.3 psi) peak positive incident pressure • structural collapse • missiles (fragments) > 11 ft-lb impact energy • thermal flux > 0.3 cal / cm^2 / sec

Table 3. Required Separation Criteria and Distances for Nearest Exposures (feet)

Exposure/Potential Explosion Site & Criteria	Site Boundary	Non Mustered Personnel	Mustered Personnel	Associated Facilities	Disposal Operators
Burn Cage (50 # NEW[a])					
Noise Criteria K=585[b]	NA	NA	NA	NA	NA
Disposal Criteria K = 328	FRAG=670	FRAG=670	FRAG=670	FRAG=670	NA
Inhabited Building Criteria K=40 (1.2 psi)	147 FRAG=670	147 FRAG=670	NA	NA	NA
Remote Criteria K=24 (2.3 psi)	88 FRAG=400	88 FRAG=400	88 FRAG=400	88 FRAG=400	88 FRAG=400
Intraline Criteria K=18 (3.5 psi)	NA	NA	66	66	66
Maximum Required Distance	670	670	400	400	400
Nearest ES and Distance from PES	East Boundary 6,225	Route 3 1,110	B812 2,520	B812 2,520	B845 660
Burn Pan (100 # NEW [a])					
Noise Criteria K=585[b]	NA	NA	NA	NA	NA
Disposal Criteria K = 328	FRAG=670	FRAG=670	FRAG=670	FRAG=670	NA
Inhabited Building Criteria K=40 (1.2 psi)	186 FRAG=670	186 FRAG=670	NA	NA	NA
Remote Criteria K=24 (2.3 psi)	111 FRAG=400	111 FRAG=400	111 FRAG=400	111 FRAG=400	111 FRAG=400
Intraline Criteria K=18 (3.5 psi)	NA	NA	84	84	84
Maximum Required Distance	670	670	670	400	400
Nearest ES and Distance from PES	East Boundary 6,225	Route 3 1,110	B812 2,520	B812 2,520	B845 660

Table 3. (Continued)

Exposure/Potential Explosion Site & Criteria	Site Boundary	Non Mustered Personnel	Mustered Personnel	Associated Facilities	Disposal Operators
Detonation Table (350 # NEW[a])					
Noise Criteria K=585[b]	4,123	4,123	4,123	4,123	4,123
Disposal Criteria K = 328	2,312 FRAG=1,250	2,312 FRAG=1,250	2,312 FRAG=1,250	2,312 FRAG=1,250	NA
Inhabited Building Criteria K=40 (1.2 psi)	282 FRAG=1,250	282 FRAG=1,250	NA	NA	NA
Remote Criteria K=24 (2.3 psi)	170 FRAG=750	170 FRAG=750	170 FRAG=750	170 FRAG=750	170 FRAG=750
Intraline Criteria K=18 (3.5 psi)	NA	NA	127	127	127
Maximum Required Distance	4,123	4,123	4,123	4,123	4,123
Nearest ES and Distance from PES	East Boundary 6,225	Control Point 4,200	B812 2,520[c]	B812 2,520[c]	B845 660[c]
B816 (45 # NEW[a])					
Noise Criteria K=585[b]	NA	NA	NA	NA	NA
Disposal Criteria K = 328	NA	NA	NA	NA	NA
Inhabited Building Criteria K=40 (1.2 psi)	142 FRAG=670	NA	142 FRAG=NA	142 FRAG=NA	142 FRAG=NA
Remote Criteria K=24 (2.3 psi)	NA	NA	NA	NA	NA
Intraline Criteria K=18 (3.5 psi)	NA	NA	64	64	64
Maximum Required Distance	670	NA	142	142	142
Nearest ES and Distance from PES	East Boundary 6,900	NA	B805 480	B805 480	B845 7,770

[a]Personal communication, Paul J. Grace , 1995.

[b]K factor noted from Appendix B of Procedure No. 300, LLNL Site 300. Meets the impulse noise criterion of 140 dB set by 29 CFR §1926.52 which is applicable to intentional detonations. All other K factors obtained from DOD 6055.9-STD and DOE 06194 (DOE,1994).

[c]Facilities are hardened against hazardous overpressures, fragments, and noise.

Table 4. Waste Forms Associated With Explosives Research and Development Operations[a]

Form 1	EXPLOSIVES REQUIRING DETONATION - Waste explosives in such a configuration that LLNL requires they be treated by open detonation. This waste form includes cased explosives or other explosives which may detonate during thermal treatment operations.
Form 2	WASTE EXPLOSIVES Form 2A - Explosive Materials and Formulations - Waste explosives powder, pastes, liquids, and pieces derived from either pure materials or formulated products. Waste explosives can also include explosive parts which have been cast, pressed, or machined to shape. Waste explosives are generated by clean-up from formulation, processing, and testing operations or by removal from inventory of stored materials or items. Form 2B - Small Explosive Assemblies or Devices - Waste explosives which are cased in a small assembly or device, such as a detonator.
Form 3	WASTES FROM EXPLOSIVES COLLECTION SYSTEMS Form 3A - Clarifier Waste - Explosives Process sludge collected from explosives processing wastewater clarifier systems. Form 3B - Weir System Waste - Explosives-contaminated sludge mixed with other debris. This waste is collected from the explosives processing wastewater weir system settlement basins.
Form 4	REACTIVE DEBRIS - Debris contaminated with energetic materials. This waste consists primarily of contaminated paper, rags, and other clean-up materials from explosives operations. The contamination is distributed in such a manner that the waste is judged to retain explosive properties.
Form 5	NON-REACTIVE DEBRIS - Debris slightly contaminated with energetic materials and similar to Form 4 with respect to the non-reactive component. The small quantities of contamination are so well dispersed that the waste does not retain explosive properties. The total quantity of contamination in the debris is controlled to trace amounts (approximately 1% or less by weight).

[a]As presented in LLNL, 1993b.

Table 5. Individual Waste Forms[a]

Waste Form 1 - Explosives Requiring Detonation

Generating Process	Configured explosives declared waste by LLNL. This waste stream consists of explosives that are no longer needed by LLNL programs for research and development and peroxides.	
Hazardous Properties	Reactive (explosive)	
Chemical Constituents and Composition (Representative for Waste Form)	Explosives (LLNL and Radian, 1992)	90-100%
	Binders (LLNL and Radian, 1992)	0-10%
Waste Codes:		
U.S. EPA	D003	Reactive Characteristic Waste
	P112	Tetranitromethane
	U117	Ethyl Ether
California	331	Off-Spec aged or surplus organics
	352	Other Organic Solids
Quantities kg (lb)	22.7 kg (50 lb)	Estimated Monthly average
	159 kg (350 lb)	Monthly maximum
	227 kg (500 lb)	Estimated Annual average
	454 kg (1,000 lb)	Annual maximum
Handling Process	Storage in containers	
Treatment Method	Open Detonation	
Treatment Unit Gross Weight Limit	159 kg (350 lb)	

Table 5. (continued)

Waste Form 2 - Waste Explosives

Generating Process	Waste explosive powders, pastes, liquids, and pieces derived from either pure materials or formulated products. Waste explosives are generated by clean-up from formulation, processing, and testing operations, or by the removal from inventory of stored materials or items. Waste explosives include explosives which are cased in a small assembly or device, such as a detonator.
Hazardous Properties	Reactive (explosive)
Chemical Constituents and Composition (Representative for Waste Form)	Explosives (LLNL and Radian, 1992) 80-100% Binders (LLNL and Radian, 1992) 0-10% Desensitizing liquid (water / alcohol) 0-20%
Waste Codes:	
U.S. EPA	D003 Reactive Characteristic Waste P081 Nitroglycerine P112 Tetranitromethane U117 Ethyl Ether U234 1,3,5-Trinitrobenzene
California	331 Aged surplus or off-specification organics 352 Other Organics 551 Laboratory Waste Chemicals
Quantities kg (lb)	27.2 kg (60 lb) Estimated Monthly average 227 kg (500 lb) Monthly maximum 340 kg (750 lb) Estimated Annual average 1,134 kg (2,500 lb) Annual maximum
Handling Process	Storage in containers
Treatment Method	Open Burning
Treatment Unit Gross Weight Limit	68 kg (150 lb) in Burn Pan

Table 5. (continued)

Waste Form 3 - Wastes from Explosives Collection Systems

Generating Process	Explosives are machined under a stream of water to decrease the sensitivity of the explosive. The water used in explosives machining operations is passed through a series of filters and clarifiers designed to remove explosives particles. Water is also used in explosives handling areas for cleaning floors and work areas of any residual explosive compounds. After passing through the filters, the water is discharged into a lined surface impoundment.
Hazardous Properties	Reactive (explosive)
Chemical Constituents and Composition (Representative for Waste Form)	Explosives (LLNL and Radian, 1992) 55-83% Binders (LLNL and Radian, 1992) 5-10% Water 10-30% Non-reactives (debris, bags, etc.) 2-15%
Waste Codes:	
U.S. EPA	K044 Wastewater treatment sludges from the manufacturing and processing explosives D003 Reactive Waste
California	491 Unspecified Sludge Waste
Quantities, kg (lb)	27.2 kg (60 lb) Estimated Monthly average 227 kg (500 lb) Monthly maximum 340 kg (750 lb) Estimated Annual average 680 kg (1,500 lb) Annual maximum
Handling Process	Storage in containers
Treatment Method	Open Burning
Treatment Unit Gross Weight Limit	118 kg (260 lb) in Burn Cage

Table 5. (continued)

Waste Form 4 - Reactive Debris

Generating Process	During the research and development of energetic materials, non-reactive materials may become contaminated with explosives to a degree that they must be disposed of as an explosives waste. This waste stream includes lab ware, wipers, and packaging materials contaminated with explosives.	
Hazardous Properties	Reactive (explosive)	
Chemical Constituents and Composition (Representative for Waste Form)	Non-reactive debris (LLNL and Radian, 1992)	80-99%
	Explosives (LLNL and Radian, 1992)	1-20%
	Acetone	0-1%
	Methyl Ethyl Ketone	0-1%
	Freon® TF	0-1%
	Methylene Chloride	0-1%
	Toluene	0-1%
Waste Codes:		
U.S. EPA	D003	Reactive Characteristic Waste
	F002	Spent halogenated solvents
	F003	Spent non-halogenated solvents
	F005	Spent non-halogenated solvents
California	352	Other Organics Solids
Quantities kg (lb)[b]	36.3 kg (80 lb)	Estimated Monthly average
	227 kg (500 lb)	Monthly maximum
	907 kg (2,000 lb)	Estimated Annual average
	1,814 kg (4,000 lb)	Annual maximum
Handling Process	Storage in containers	
Treatment Method	Open Burning	
Treatment Unit Gross Weight Limit	118 kg (260 lb) in Burn Cage	

Table 5. (continued)

Waste Form 5 - Non-Reactive Debris

Generating Process	This waste form is generated in the same manner as Form 4 with the exception that the amount of explosive contained in this waste stream is in such a configuration that no potential for explosion exists. This waste form may burn more vigorously when ignited than a non-explosive contaminated waste stream.
Hazardous Properties	Ignitable
Chemical Constituents and Composition (Representative for Waste Form)	Non-reactive debris (LLNL and Radian, 1992) 94-100% Explosives (LLNL and Radian, 1992) 0-1% Acetone 0-1% Methyl Ethyl Ketone 0-1% Freon TF 0-1% Methylene Chloride 0-1% Toluene 0-1%
Waste Codes: **U.S. EPA** **California**	 D001 Ignitable F002 Spent halogenated solvents F003 Spent non-halogenated solvents F005 Spent non-halogenated solvents 352 Other Organics
Quantities kg (lb)[b]	36.3 kg (80 lb) Estimated Monthly average 227 kg (500 lb) Monthly maximum 907 kg (2,000 lb) Estimated Annual average 1814 kg (4,000 lb) Annual maximum
Handling Process	Storage in containers
Treatment Method	Open burning or incineration (off-site)
Treatment Unit Gross Weight Limit	NA

[a] presented in LLNL, 1993b.

[b] Estimates for combined Form 4 and Form 5 wastes.

Table 6. Toxic Combustion Products

	Explosive	EA for HEAF [a] kg/kg HE	Ornellas [b] mol/mol HE	Mass Balance [c] mol/mol HE
HF	LX-17	4.00E-02	NA	4.00E-02
	LX-04	1.04E-01	1.04E-01	1.04E-01
	LX-10	NA	NA	3.40E-02
HCl	LX-17	7.00E-02	NA	1.97E-02
	PBX-9404	1.10E-02	NA	1.09E-02
HCN	Comp B	NA	4.32E-03	
	Octol	NA	3.78E-03	
	RDX	NA	3.53E-03	
	TATB (LX-17)	2.00E-03	1.47E-03	
	TNT	2.40E-02	2.36E-02	
	HMX	7.00E-04	7.39E-04	
NH_3	TATB	7.00E-03	7.25E-03	
	HMX	2.30E-02	2.24E-02	
	PETN	2.70E-03	3.01E-03	
	TNT	1.50E-02	1.93E-02	
	Comp B	NA	2.16E-02	
	RDX	NA	2.14E-03	
	LX-04	NA	4.08E-04	
	LX-11	NA	1.58E-02	
	Octol	NA	2.30E-02	

[a] DOE, 1989
[b] Ornellas, 1982
[c] Project File

Table 7. Hazard Identification Table for the EWSF (B816) and EWTF

Electrical Sources
- Capacitors
- Batteries
- Exposed conductors
- Static electricity
- Lightning
- Other high-voltage sources

Chemical Sources
- Toxic materials
- Corrosive materials
- Flammable materials
- Reactive materials
- Pathogenic materials
- Carcinogenic materials

Pressure Sources
- Explosives
- Noise
- Chemical reactions
- Stressed mechanical systems

Cold Sources
- Ice
- Snow
- Wind
- Rain

Motion Sources
- Vehicles
- Burn pan lid
- Projectiles

Biological Sources
- Black Widow spiders
- Poisonous snakes
- Valley Fever
- Bees, wasps
- Scorpions

Heat Sources
- Electrical
- Friction
- Solar
- Flames
- Chemical reactions
- Spontaneous combustion

Gravity-Mass Sources
- Falling
- Falling objects
- Lifting
- Tripping, slipping
- Earthquakes

Radiant Sources
- Ultraviolet
- Solar

Table 8. Hazards Characterization Table: Explosives Waste Facilities and B816

Hazards Characterization Table: Explosive Waste Treatment Facilities and Building 816

Event Number/ Postulated Event Description	Causes	Prevention Features		Method of Detection	Mitigation Features		Consequences
		Design	Administrative		Design	Administrative	
1. Fire in B816	Power lines; cigarettes; hot exhaust pipes from vehicles; lightning	Firebreaks; power line separation	Site 300 Safety Manual prohibits smoking, ignition sources, and requires spark arrestors	Visual	Maintenance of firebreaks in surrounding land	LLNL Fire Department; cooperative agreements with area fire departments; controls on vegetation (controlled burning or herbicide use); maintenance of firebreaks; parking and vehicle restrictions	Cost of fire fighting; potential loss of buildings, dwellings; damage to surrounding private land; potential injuries and loss of life
2. Grass fire	Wind gusts blow hot ash; undetonated projectiles; power lines; cigarettes; hot exhaust pipes from vehicles; lightning; leaking propane; uncontrolled vegetation	Sheltered location; firebreaks; power line separation; power line burial	Local weather reports; permission to burn from San Joaquin County Air Pollution Control District; Site 300 Safety Manual prohibits smoking, ignition sources, and requires spark arrestors	Visual	Maintenance of firebreaks in surrounding land	LLNL Fire Department; cooperative agreements with area fire departments; controls on vegetation (controlled burning or herbicide use); maintenance of firebreaks; parking and vehicle restrictions	Cost of fire fighting; potential loss of buildings, dwellings; damage to surrounding private land; potential injuries and loss of life
3. Unintentional detonation in the OB area	Incompatible mix of wastes; inadequate analysis of explosives; inclusion of a natural detonator; autocatalytic; lightning; fire; human error; friction; electrical spark; shock; earthquake; spilled wastes; vehicles	Power line separation; power line burial	OSP's; UNO compatibility guidelines; supervision by a trained explosives expert; prohibition of containers that confine explosives; operations prohibited during and before electrical storms; Site 300 Safety Manual; DOE Explosives Manual; no smoking; no spark-producing equipment; training	Visual (remote video and line-of-sight)/audi-tory	Earth barricades for shielding; burn unit and pan physical features; Quantity-Distance requirements	Limitations on quantity of explosives waste for any burn; personnel limits; weekly inspection of treatment units; muster procedures; vehicle restrictions	Injury/death; loss of property and equipment; possibility of fragment puncturing propane tank and causing secondary explosion

Table 8. (continued)

Event Number/ Postulated Event Description	Causes	Prevention Features		Method of Detection	Mitigation Features		Consequences
		Design	Administrative		Design	Administrative	
4. Premature initiation in OD area	Detonators go off too early; human error: dropping a piece onto a full table; wrong type initiators; lightning; friction; electrical spark; shock; earthquake; spilled wastes; vehicles	Barricades around tank	OSP and Explosives Safety Manual limit what is put together and control two-way radios in area; operations prohibited during and before electrical storms; Site 300 Safety Manual; DOE Explosives Manual; no smoking; no spark - producing equipment; training	Visual/ auditory	Earth barricades; quantity distance requirements	Limitations on quantity of explosives waste for each detonation and having only what is to be treated in the area; personnel limits; weekly inspection of treatment units; muster procedures; vehicle restrictions	Injury/death; loss of property
5. Dispersal of wastes	Failure of containers; mishandling of explosives; run-on and run-off of treatment units	None	Require strapping around containers; training in explosives handling	Visual	No run-on trenching	Personal protective equipment	Skin, eye, respiratory irritations; detonations; soil contamination
6. Air dispersal of combustion products	Deflagration or detonation	None	None	Air monitoring stations	None	Controls on operations (only during proper weather conditions) and quantities of wastes	Soil contamination
7. Incompletely treated piece of explosives as ejecta	During intentional or unintentional detonation	None	Procedures for detonating; no encased explosives; configurations	Visual	Video monitoring to detect	Inspections of area; procedures to handle incompletely treated explosives	Death/injury; property damage
8. Leak of propane tank	Hit by a fragment from a detonation; valve/ piping failure struck by vehicle	Separation distance and earth barri-cade between; power line separation; power line burial	None	Visual	None	None	Vapors and possible fire or explosion
9. Noise: as it affects workers and as it affects general public	Explosions	None	Muster procedures	Auditory; medical examinations	Bunker design; remote location	Quantitative limitations based on weather reports and computer code calculations; personal protective equipment; medical treatment (hearing) conservation	Hearing loss; complaints from public
10. Personnel in danger zone during normal OD operations	Failure of muster controls; muster procedures	Gates and interlocks	Observation point manning	Visual	None	None	Injury/death

Table 9. Variables Used in the Air Dispersion Modeling

Scenario	Plume Rise/Cloud Top (PR/CT) Estimation (m)	Radius of Area-Term[a] Release (m)	Worst-case atmospheric stability class[b] for receptor distance of 1.85 km	Worst-case wind speed (m/s)
Fire	11 m[c]	1 m	E	10
Explosion[d]	$76 (W^{e})^{0.25}$ =CT	$0.2*76(W)^{0.25}$ = 69 m	F	1

[a] Type of Gaussian model used to estimate air concentrations at distance x.

[b] Based on Pasquill stability types, refers to how a parcel of air would react when it is displaced adiabatically in the vertical direction: A, extremely unstable; B, moderately unstable; C, slightly unstable; D, neutral; E, slightly stable; F, moderately stable.

[c] Assumes a burn temperature of approximately 200^{o} C, 11 m / s wind speed, worst-case stability.

[d] This cloud top estimation assumes that the cloud resulting from the explosion dissipates 80 percent of the decomposition products. Based on an analysis by Lane, 1994, 80 percent of the source term contributes insignificant additional dose to the receptor whenever the dispersion of an explosion of 1 lb of HE or more is modeled.

[e] W equals the TNT equivalent weight of the explosives, in lb. For LX-04-01, this is (350 lb) (1.23) =430.5 lb.

Table 10. Parameters Assumed for the Air Dispersion Modeling

Scenario	Source Term (kg of HF) and release fraction	X/Q at 1.85 km (s/m^3)	Duration of Release (seconds)
Fire	$Imax_1$ = 16.5 RF_1 = 1.0	1.1 E-05	t_1 =600
Explosion	$Imax_2$ = 16.5 RF_2[a]= 0.04	contribution from ground level : 1.8E-06 contribution from 69 m height: 6.9 E-08	t_2 =1

[a] This estimation assumes that the cloud resulting from the explosion dissipates 80 percent of the decomposition products, thus only 20 percent of the material at risk is available to the receptor of interest, based on an inhalation dose, (Lane 1994). Lane presents a mathematical argument which demonstrates that 80 percent of the source term contributes an insignificant amount to the receptor's dose whenever the dispersion of an explosion of 1 lb of HE or more is modeled.

Table 11. Worst-Case Airborne Concentrations of Hydrogen Fluoride

Scenario Description **159 kg** **(350 lb)** **of LX-04-01**	**DOE Benchmark Concentration at 0.1 km** **4.5 m/s wind speed;** **D atmospheric stability**	**Predicted Concentration at 7.5 m/s wind speed;** **Pasquill atmospheric stability**	**ERPG -Levels[a]** **-1: 4.1 mg/m^3** **-2: 16.4 mg/m^3** **-3: 41 mg/m^3**
DOE Benchmark Concentration at 100 m (328 ft) **Fire (Explosion)**	0.45 mg / m^3 (44 mg / m^3)	N / A	< ERPG-1 4.1 > ERPG-3 41
EWTF **1.8 km (1.1 mi) to fence line**	N / A	Fire: 0.29 mg / m^3 Explosion: 1.4 mg / m^3	< ERPG-1 4.1 < ERPG-1 4.1

[a] The American Industrial Hygiene Association's (AIHA) Emergency Response Planning Guide Level 1 for hydrogen fluoride: the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor (AIHA, 1988). ERPG Level 2 for hydrogen fluoride: the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action. ERPG Level 3 for hydrogen fluoride: the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Table 12. Comparison of Worst-Case Airborne Concentrations to Several Commonly Accepted Dose Response Values

Description	**Airborne Concentration**
Highest tolerable concentration: irritates skin, eyes and respiratory system.	100 mg / m^3; 1 minute
≥ERPG-3: Life threatening health effects	41 mg / m^3; 1 hour maximum
>ERPG-2<ERPG-3: irreversible, serious health effects, may impair one's ability to take protective action.	<41 mg / m^3 < 1 hour
<ERPG-2: the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1-hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.	16.4 mg / m^3
< ERPG-1	<4.1 mg / m^3
TLV-TWA Ceiling	2.6 mg / m^3
Pungent irritating odor threshold	0.03-0.1 mg / m^3

Table 13. Consequence Levels

Consequence Level	Category	Maximum Consequences
1	High	Serious impact on site or off site. May cause death or loss of the facility / operation. Major impact on the environment.
2	Medium	Major impact on site and / or minor impact off site. May cause severe injury or severe occupational illness to personnel or major damage to a facility / operation or minor impact to the environment. Capable of returning to operation.
3	Low	Minor on site, with no off-site impact. May cause minor injury or minor occupational illness, or minor impact on the environment.
4	Extremely Low	Will not result in a significant injury, occupational illness, or impact on the environment.

Table 14. Probability Levels

Probability Level			Estimate Range of Occurrence Rate per Year
Category	Level	Description	
Incredible	E	Probability of occurrence is so small that a reasonable scenario is not conceivable. These events are not considered in design or Safety Analysis Document accident analysis.	≤ 10 -6
Extremely Low	D	Probability of occurrence is extremely unlikely or event is not expected to occur during the life of the facility or operation.	≥10 -6 and ≤10 -4
Low	C	Probability of occurrence is unlikely, or event is not expected to occur, but may occur during the life of the facility or operation.	≥10 -4 and ≤10 -2
Medium	B	Event is likely to occur during the facility or operation lifetime.	≥10 -2 and ≤10 -1
High	A	Event is likely to occur several times during the facility or operation lifetime.	≤10 -1

Table 15. Risk Characterization

Event #	Event	Consequences [a]	Probability [b]	Risk [c]	Acceptable/ Unacceptable [d]
1	Fire in B816	2	C	L	A
2	Grass fire	2	C	L	A
3	Unintentional detonation in the OB area	1	D	L	A
4	Premature initiation in OD area	1	D	L	A
5	Dispersal of wastes	2	C	L	A
6	Air dispersal of combustion products	4	A	L	A
7	Undetonated piece of explosives as ejecta	2	C	L	A
8	Leak of propane leak	4	D	N	A
9	Noise as it affects workers and as it affects general public	3	C	N	A
10	Personnel in danger zone during normal OD operations	2	C	L	A

[a] as determined from Table 13

[b] as determined from Table 14

[c] H=high, M=medium, L=low, N=negligible

[d] A = acceptable, N = unacceptable

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